The stratigraphy and structure of the area between middleton-in-teesdale and woodlands

Jones, H. Li. L.

THE STRATIGRAPHY AND STRUCTURE
OF THE
AREA BETWEEN
MIDDLETON-IN-TEESDALE
AND
WOODLANDS

By H. Ll. L. Jones, B.Sc. (Wales).

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FRONTISPIECE.

A view of part of Crossthwaite Common showing the effect on the Whin scarp of the Southern Teesdale Fault. The fault throws south and dies out to the south east (i.e. to the left of the photograph). Below the scarp some of the thick drift which flanks the Tees can be seen, while above, beds of the Middle Limestone Group give rise to the various features of Harter Fell locally obscured by patches of drift on the lower slopes.

PREFACE AND ACKNOWLEDGEMENTS.

The area investigated, lying between Middleton-in-Teesdale in the west, and Woodlands in the east, was covered by the Geological Survey Old Series 1 inch Sheets 102 N.E., 102 S.E., 103 N.W., 103 S.W., published in 1881 and revised in 1889. The region was surveyed by H.M. Howell, W.T. Aveline, D. Burns, W.Gunn, T.E. Clough, J.R. Dakyns, R.H. Tiddeman, T. McKenny Hughes, R. Russell, W.H. Dalton, and J.G. Goodchild between 1869 and 1881, on a scale of 6 inches to 1 mile. No memoir was published with the maps so that details of the succession were largely unknown, apart from those given in a memoir dealing primarily with the ore deposits of the Northern Pennines (1948).

Since the primary survey important advances have been made in the Carboniferous geology of Northern England, and in the light of these modern developments there was a need for a resurvey of this part of the Alston Block. Recent work undertaken in adjacent areas to the south, particularly the Cotherstone (Stainmore) area, has underlined the necessity for a re-examination and more detailed treatment of the succession. In addition, serious uncertainties about the geological structure north of Middleton-in-Teesdale remained after the primary survey.

Apart from this, the main purpose of this survey has been to clarify the position regarding the so-called "Millstone Grit". The primary surveyors mapped three grits with associated shales and sandstones, but evidence from boreholes sunk since the original survey suggests that their interpretation was over-simplified. The object, therefore, has been to establish the truth or otherwise of this original interpretation; to work out a more detailed succession; to correlate these beds with the "Millstone Grit" of outside areas if possible, and to attempt an establishment of their true age relationships. The area of outcrop of the "Millstone Grit" is rapidly becoming obscured by the growth of the Hamsterley National Forest, and this also made a resurvey desirable.

The work was commenced in October 1953, originally sponsored by the Shell Petroleum Company, to whom the author is indebted. Field work was carried out during the periods October to December 1953, April to November 1954, and March to June 1955.

The author's thanks are due to Dr. G.A.L. Johnson for his advice on palaeontological problems; to the various members of the staff and research department for helpful discussion; and to the Laboratory staff for their technical assistance. He is particularly indebted to Professor K.C. Dunham for suggesting the course of research, carried out in the Department of Geology, Durham Colleges, and for advice, constructive criticism, and encouragement throughout its progress.

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CHAPTER 1

INTRODUCTION.

GEOGRAPHY

Physical Geography.

Bounded on the north, west, and south by major fault systems, the Stublick Fault, Pennine-Dent Faults, and the Craven Fault System, respectively, the Northern Pennines form a well-defined structural unit which is divided into two complementary areas by the east-west trending Stainmore depression. The two halves
have been designated the Askrigg Block (R.G. Hudson, 1938) in the 3)
south, and the Alston Block (F.M. Trotter, and S.E. Hollingworth, (2)
1928) in the north, the whole being called the Northumbrian Fault (1)
Block (Marr, 1921).

The Alston Block is an uplifted area presenting a fault - scarp face to the west towards the Vale of Eden and overlooking the Tyne Gap to the north, while to the south it sweeps down into the topographical and geological depression of Stainmore. The block is tilted slightly to the east and the high moorlands of the west descend gradually to the less austere, more rolling country of the Durham Coalfield.

The area under consideration occupies a strip of country on the southern margin of the Alston Block, encroaching upon the Stainmore Syncline on the south-west. It extends from just above the Whin Sill scar on the Yorkshire side of the Tees to the western margin of the Durham Coalfield near Woodlands. The boundaries are arbitrary lines having little geographical or geological significance.

These delimitations enclose a high moorland area with the higher ground ranging from 2,185 feet O.D. on James' Hill (322924) in the west, to 1,285 feet O.D. on Black Hill (304035) in the east. This disparity in height reflects the general easterly tilt of the area, attributed to Tertiary uplift.

The high moorlands, or fells, are broad, peat-covered tracts largely dominated, in this area, by the feature-forming "Mill-stone Grits", and represent a gently tilted plateau, now deeply dissected by streams. The most important of these streams is the River Tees, flowing in a south easterly direction across the south-western margin of the area through a broad vale. Running across the area from N.W. - S.E., and then swinging to a N. - S., direction, is the Tees-Wear watershed from which the tributaries of the Tees run in a southerly direction, while in the north-east Ayhope Beck, Euden Beck, and Spurlswood Beck run eastwards and north-eastwards to join the River Wear to the east.

Much of the land is enclosed by dry stone walls which date from the time of the enclosures in the 1870's. The flat fell-tops, with the thick peat deeply dissected into haggs, are generally bleak open moorlands covered with heather and inhabited by grouse, lapwings and curlews.

Human Geography.

Some ancient relics afford a fascinating glimpse of the earliest inhabitants of the Dales. Flint arrowheads have been found at Park End, Holwick, on Cronkley Scar and Harter Fell, and in the peat on Mickle Fell; a bronze palstave which formed the head of an axe was found in Hudeshope Beck near Middleton - in - Teesdale in 1927. These can now be seen in the Teesdale room of Bowes Museum.

State here and grid ref

On Foggerthwaite, near Eggleston, the Standing Stones (252983) which have been removed for walling and road mending were described by Hutchinson (1794) thus;
"A uniform circle of rough stones with an inward trench, and in the centre a cairn; much of the material has been taken away to repair roads. At a small distance and close by a brook, is a large tumulus, crossed from east to west by a row of stones. The adjacent ground, forming an inclined plane, was probably a field of battle." The date of the circle is uncertain but thought to be Bronze Age; the tumulus is a round barrow associated with the early and middle parts of the Bronze Age.

In Lunedale, on Bail Hill (226970) an early Bronze Age burial was discovered in a field in the early part of the nineteenth century. The body was buried in a crouching position with knees close up to the chin, which is characteristic of the Beaker Folk.

Less spectacular evidence of earlier inhabitants is to be found in the local place-names. The river names are the oldest of the place-names, going back to the era of the first Celtic settlers. The Tees is mentioned as "Tesa" in the Knythinga Saga, the history of the Danish kings of the tenth and eleventh centuries. It changes later to "Teisa" and "Taise" (D.M.Ramsden, 1947). Prof., Ekwall calls it an old British river name related to the Welsh "tes" meaning "heat" or "sunshine", and translates it as the "boiling, surging river."

The local name for waterfall, "force" is similar to the Norwegian and Icelandic "foss." "Fell" is used like "fjell" in Norway and "fell" in Iceland. These and other names bear testimony to the coming of later settlers of Norwegian descent who came by way of Ireland and N.W. England and entered Teesdale through Stainmore and other passes.

The Angles, Danes, and Norwegians have all left their mark on local place-names. "Cotherstone, Lartington, Mickleton and Middleton must have started as single farms occupied by a family and enclosed by wooden stockades" (Ramsden p.13). "Tun" is still used in Iceland for a farm with its surrounding walls. Thus Mickleton was the large farm, and Mickle Fell, the great fell. Harter's Fell recalls the old Forest of Teesdale, while "thwaite" as in Crossthwaite and Foggerthwaite, meant a field cleared from woodland.

The present population is centred in the villages of Middleton (1603), Eggleston (414), Newbiggin (244), Mickleton (465), and Romaldkirk (190). The figures for the two latter villages are taken from the Startforth R.D.C. 1948 census (the last one recorded), the others from the 1951 census of the Barnard Castle R.D.C.

Economic Geography.

The economic activities of the dale include agriculture, quarrying, and mining.

Haytime is the most important season in the farming year for the dalesmen. Except at haytime, the farmer's interests are centred mainly around the large flocks of sheep, mainly Swaledales, which most own. In addition a few cattle, pigs, and poultry are kept. Many of the Upper Teesdale farms are little more than crofts and the men who work them often began in the quarries or mines before accumulating sufficient capital to start farming.

Large quarries in the Whin Sill and the Great Limestone scar the dale and form its main mineral wealth today. The Scar Limestone is also worked on a smaller scale, the quarry in Bow Lee Beck valley, near Newbiggin, now being the only one still in operation. Small, disused sandstone quarries are numerous, the stone being utilized for local building, including the extensive dry stone walls.

Lime burning is another old industry in Teesdale. Many of the farms had their own lime-kilns at one time, but these have now fallen into disuse. The lime-kilns situated at Skears Quarry (272948) in Hudes Hope near Middleton -in- Teesdale still carry on the work.

With the exception of the lead-mine at Coldberry (291943), which was reopened in 1951, mining, once the economic mainstay of the dale, has ceased, the activities dying out early this century. Sharnberry Low Level, however, is being reopened with a view to exploiting reserves of fluorspar.

Local tradition has it that the Romans worked the hills of Upper Teesdale for lead, but there is no conclusive evidence to support this. It is by no means impossible however, in view of the fact that they did work the lead of Swaledale.

Old implements, picks and crowbars, have been found in "t'owd man" levels of Weardale, but their date is uncertain. The hills of the dale are pock-marked with the scars of old workings and the oldest of them have been taken back into the hillsides. The levels have collapsed and the entrances show as slight hollows in the turf with grass-covered mounds of excavated material below them.

References to lead and silver mines in various parts of the Northern Pennine Orefield date back to the early twelfth century (Dunham 1948, p.4) and place on record more or less continuous activity in the following centuries. Dunham (1948) draws our attention to the discovery of coins dating from the reign of William Rufus in an old drift on Browngill Vein, which established that mining was in progress shortly after the Norman Conquest.

There is evidence of early, primitive smelting operations which Hutchinson refers to in "The History and Antiquities of the County Palatine of Durham" (1794). Writing of the Eggleston district he mentions "Several ancient basins formed of stone work scattered over the moor wherein lead ore was smelted, or run by force of fuel heaped upon it, assisted by the wind, before a mill or bellows was used." Fragments of dark vitreous slag were found concentrated in a restricted area near Windy Hill (223017) approximately 1½ miles south east of Eggleston, during the present survey.

The method used by early prospectors to locate mineral veins known as "hushing" has left its mark upon the countryside. High on the fells a stream was dammed to form a reservoir and the water was then released in a torrent down the hillside, removing the covering of soil and loose rock. The most striking of these hushes is Coldberry Gutter, above Red Grooves, near Newbiggin. Cut along the line of the Lodgesike - Manorgill Vein, it can be

Plate I.

Coldberry Mine and Coldberry Gutter from Monks. The gutter is the deep knick seen in the middle distance skyline.

seen as a large gap in the northern ridge of the valley from the High Force road, (pl.1, p.7).

The London Lead Company came to Teesdale by way of Alston Moor and the South Tyne Valley about the middle of the eighteenth century. The first lease in Teesdale was in 1752 (Dunham, or 1753 - Ramsden) of certain mines near Newbiggin, and was followed in 1771 by the lease of the mines and smelt mills at Eggleston (Ramsden). From then until the time it was finally wound up in 1905, the London Lead Company played a prominent part in the life of Upper Teesdale. The mines were widely scattered in the dale, its tributary valleys, and on its verges, with the largest concentration of productive mines in the region just north of Middleton - in - Teesdale. The first smelt mill at Eggleston was opened in 1771, and two others were added later as extensions. These were situated in Blackton Beck Valley (252997) and ore was carried there from the mines along roads constructed by the Company. This was the only smelting centre owned by the Company, but an earlier one existed in Langdon Beck valley about which little is known.

The industry declined towards the end of the nineteenth century when many of the veins were worked out and competition from richer and more easily mined ores from abroad increased.

A little iron ore has been obtained from Bands Vein, two miles north west of Langdon Beck Hotel, in the Jew and Tynebottom Limestones (Dunham, 1948, p.291).

On the western edge of the Durham Coalfields, near Woodlands, the Brockwell Coal has been extensively worked, but activities have now ceased.

The dale is largely indebted to the London Lead Company for its present road system. A new road was proposed in the nineteenth century and later carried out by the Company, Greenwich Hospital and other interested authorities, and ran the length of Teesdale through Middleton to Alston. This is now the main road to Alston which crosses Yad Moss at a height just below 2,000 feet O.D. The roads from Middleton through Lunedale to Brough, and from Middleton and Eggleston to Stanhope were proposed and largely built by the Company. The roads over the high moors from Teesdale and Alston into Westmorland and from Newbiggin into Weardale by Swinhopehead were also built for the mines, but have now fallen into disuse.

Middleton is also the terminus of a branch line of the British Railways, formerly the L.N.E.R.

GEOLOGY

The Alston Block.

There is evidence that the Alston Block existed in Devonian times. Prof. O.T.Jones has suggested that the Lower Palaeozoic rocks beneath the Carboniferous sediments of the Alston Block are comparatively thin and underlain at no great depth by an Archaean core. Trotter and Hollingworth (1928) suggest that the pre-Carboniferous Middle Pennine Fault, which has a westerly downthrow of 20,000 feet, may be regarded as an "expression of the western edge of the Alston Block in Devonian times."

The latter authors also recognised that the Alston Block behaved as an independent unit during Carboniferous times and that the Northumbrian Fault Block as a whole was flanked on three sides by geosynclinal troughs of sedimentation. On the north lay the Northumberland Trough, on the south the Pendle or Bowland Trough, and on the west, a trough extending from Ravenstonedale in the south, to the Brampton district in the north. Sedimentation within these troughs commenced in Z times (query) in the Bowkand Trough and in C1 times in the northern and western troughs. Zone

Four main divisions have been recognised in the Carboniferous Limestone Series of the Alston Block. Firstly a Basement Group including the basal Carboniferous conglomerates and south of the South Swindale Beck Fault, in the south western part of the block, beds placed by Garwood (1912) in his Athyris glabristria, Michelina grandis, and Productus corrugato-hemisphericus subzones. These latter correspond respectively with the C1, C2, and S zones ofVaughan's South Western Province. Over the remainder of the block however, the earliest beds belong to the Nematophyllum minus (S2) subzone of Garwood.

The succeeding beds of the Carboniferous Limestone Series were subdivided by R.G.Carruthers and other workers in the Belford and Holy Island Memoir (1927) into the Lower, Middle, and Upper Limestone Groups of the Upper Bernician, and this practice was adopted by Trotter and Hollingworth in the Brampton district (1932). Dunham (1948) referred to the three divisions as the Lower, Middle and Upper Limestone Groups without the use of the term "Bernician". The Lower Limestone Group covered the Lower Dibunophyllum (D1) subzone including beds from the non-sequence above the Bryozoa Band occurring near the bottom of the Melmerby

Scar Limestone (Turner 1927, pp. 344,357), up to the base of the Smiddy Limestone. The latter limestone, which contains the Girvanella Band (base of D2) is taken as the basal member of the Middle Limestone Group. The top of the D2 subzone is controversial. Dunham (1948) took the base of the Great Limestone as the top of the Middle Limestone Group, following the practice of Trotter and Hollingworth (1932, p.52). Garwood regarded the Orionastraea Band, which Turner (1927) identified with the Tynebottom and Single Post Limestones, as the base of the D3 subzone as understood in Derbyshire (1924). The Middle Limestone Group was assigned by S.Smith (1910) to the D2-3 subzones, with the Upper Limestone Group allocated to Dy. Trotter and Hollingworth (1932 p.16) placed the former group in the D2 subzone and the latter group in Dy. Dunham's Upper Limestone Group extended from the base of the Great Limestone to the base of the local "Millstone Grit." (1948)

The term "Yoredaleian" was recommended by a Committee of the British Association in 1925, as a new major division of the Lower Carboniferous, for beds above D1 in the North of England. W.P.Hedley (1931) used the term for the beds above the Single Post Limestone to the top of the Upper Limestone Group.

Hill (1938) divided the beds above the Single Post Limestone into two coral zones. The lower zone, No. 3, extended to the top of the Great Limestone, and contained Diphyphyllum and Palaeosmilia regia. The upper, No. 4, zone did not contain these forms.

Critical palaeontological evidence, particularly of goniatites, is sadly lacking from the Alston Block, but correlations of various horizons with outside areas better endowed with such evidence, throws some light on the age relationships of the succession. Thus, as Dunham points out (1948 p.12) part, if not most of the Middle Limestone Group, is probably of P zone age, while much of the Upper Limestone Group will probably be assigned to the E zone. If this be the case, then the Upper, and some of the beds of the Middle Limestone Group are equivalent to the Millstone Grit of Yorkshire and Lancashire. Carruthers (1938) has indicated his opinion that the Northern Pennines "Millstone Grit" represents only part of the Yorkshire Millstone Grit.

The succession in the area under consideration extends from the Tynebottom Limestone, within the Middle Limestone Group, to the Brockwell Coal, near the base of the Middle Coal Measures.

The Carboniferous Limestone Series has been sub-divided along the lines followed by Dunham (1948), into the Middle and Upper Limestone Groups, the Great Limestone being taken as the basal member of the latter. No time significance is herein intended by the use of the term "Millstone Grit", it is merely retained as a useful term with lithological significance, and is consistent with the practice adopted in this area by previous workers such as Westgarth Forster (1809 - see chapter 4 following) the Primary Surveyors (1869-1881), R.G.Carruthers (1938), and K.C.Dunham (1948)

Recent workers, including K.C.Dunham (1948), H.G.Reading (1954), and A.J.Wells (1955), in dealing with the Carboniferous succession in various parts of the Northern Pennines, have resorted to "cyclothems" as units of treatment. While this is recognised as a desirable and logical course to follow in suitable areas, it is felt that such a procedure would be unwise in this instance, where areas covered by individual cyclothems are restricted and would result in a piecemeal treatment of the area as a whole. It is proposed, therefore, to treat the Carboniferous Limestone Series in two parts, the first dealing with the Middle Limestone Group, the second with the Upper Limestone Group. The "Millstone Grits" are treated individually, the strata succeeding each grit being treated in conjunction with that grit.

Geological Succession.

Superficial Formations.

		Thickness.
Recent :	Hill Peat	up to 10 ft.
Pleistocene. :	Glacial sand and gravel and boulder clay.	up to 100 ft.

Solid Formations.

Carboniferous.

Lower Coal Measures :	poorly exposed - grits, sandstones, shales, and the Brockwell Coal.	up to 200 ft.
"Millstone Grit":	five coarse grits, with sandstones, shales, ganisters and thin coals.	350 - 450 ft.

Unconformity.

Carboniferous Limestone Series :

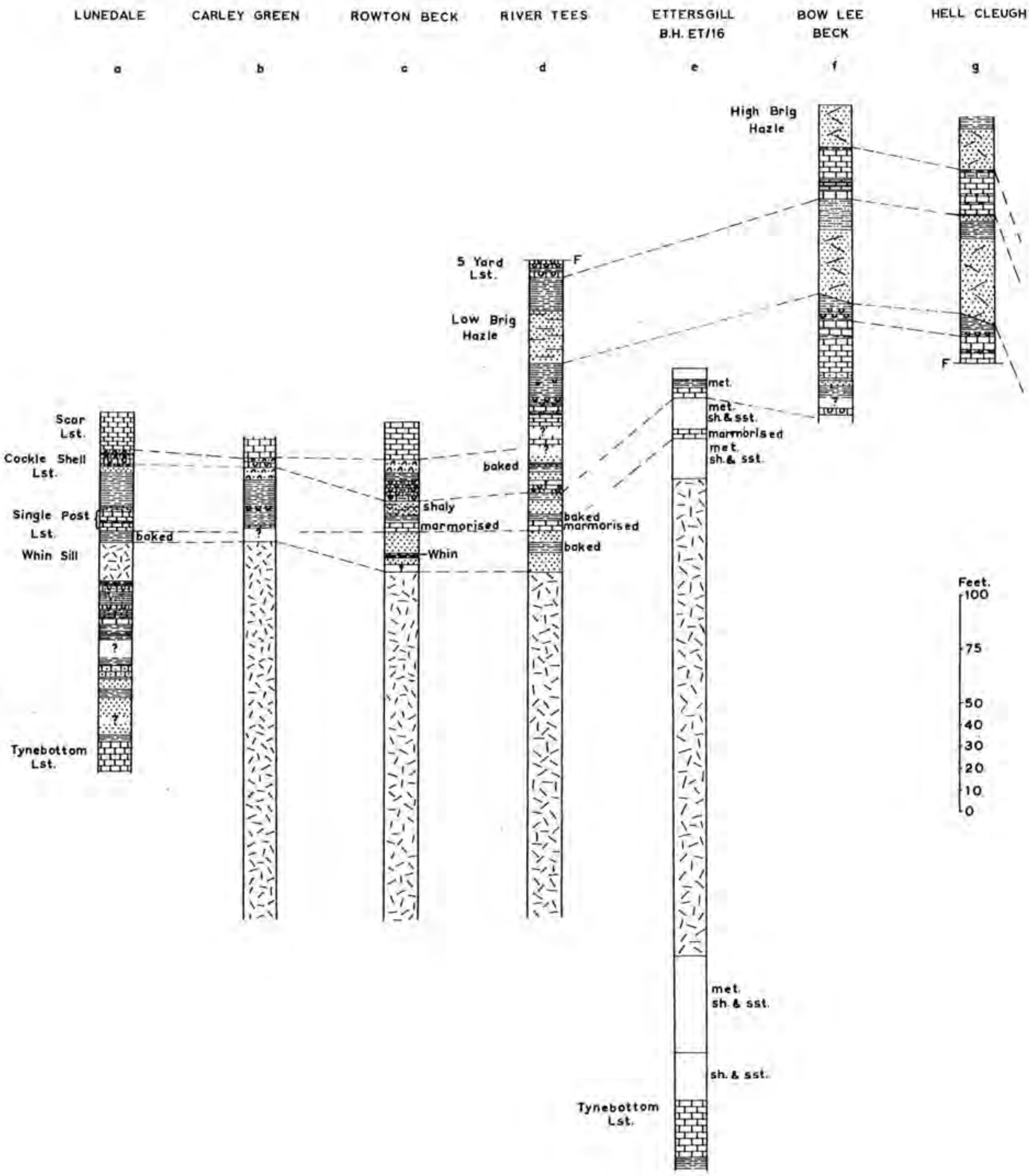
Upper Limestone Group :	coarse grits, sandstones, ganisters, thin coals, shales, and limestones. Unconformities at base of Grit Sills, and especially at base of Transgression Beds Grit.	600 - 700 ft.
Part of Middle Limestone Group :	rhythmically alternating limestones shales, sandstones, ganisters and thin coals.	400 - 450 ft.

The resurvey was carried out on a scale of 6 inches to 1 mile the following Ordnance Survey sheets being used.

Durham Sheets: XXX1, XXX11, XXX1X, XLV1, XL.

Yorkshire Sheets: 11, 1V, V.

? II not 11


LUNEDALE
CARLEY GREEN
ROWTON BECK
RIVER TEES
ETTERSGILL
B.H. ET/16
BOW LEE
BECK
HELL CLEUGH
a
b
c
d
e
f
g
High Brig
Hazle
5 Yard
Lst.
F
Low Brig
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met.
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Scar
Lst.
Cockle Shell
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Single Post
Lst.
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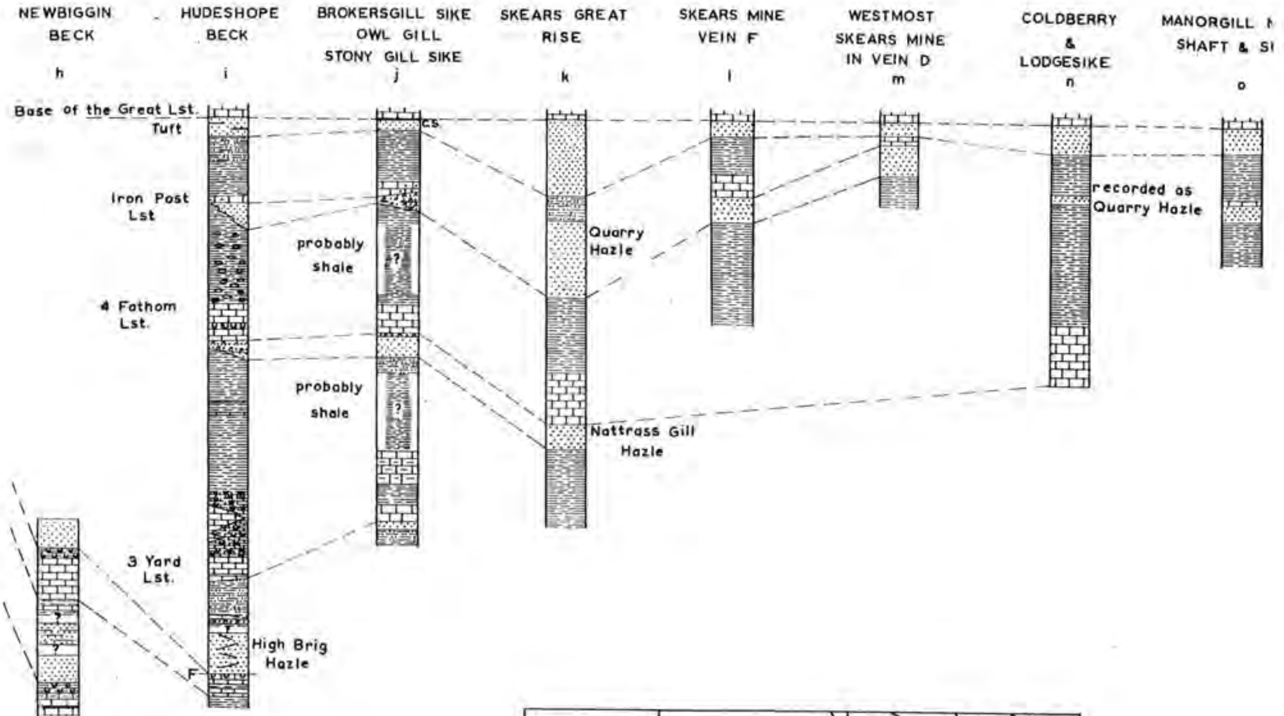


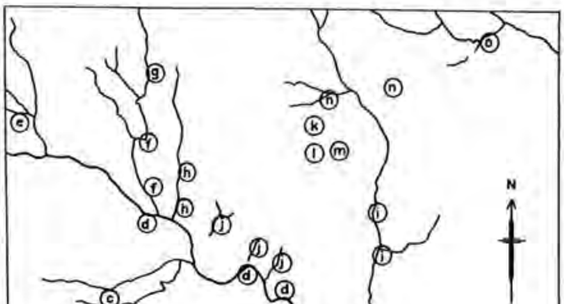


Fig. 1 COMPARATIVE SECTIONS of the MIDDLE LIMESTONE GROUP

CHAPTER 2

THE MIDDLE LIMESTONE GROUP

GENERAL STRATIGRAPHY

The strata dealt with in this chapter include beds from the Tynebottom Limestone, only part of which is exposed, up to the base of the Great Limestone. The sequence of these beds is set out in figure 1, (p. 14). In this and succeeding chapters the terminology used is largely that employed by Westgarth Forster (1809), John Phillips (1836), and the Geological Survey. Names of beds introduced by other workers will be discussed in the relevant sections.

For purposes of detailed description, the succession has been arbitrarily divided into three subgroups, because treatment of the group as a whole would be unwieldy. The subgroups consist of:

a) Strata up to the base of the Five Yard Limestone.
b) Succeeding strata up to the base of the Four Fathom Limestone.
c) Succeeding strata up to the base of the Great Limestone.

Each subgroup has then been described under locality headings.

The section of the Middle Limestone Group represented here, outcrops on the south-western flanks of the area: in Lunedale; Crossthwaite Common; in the River Tees between Scoberry Bridge (911274) and the mouth of Intake Sike (942253); in the northern tributaries of the Tees, generally extending shorter distances to the north up the tributary valleys as the regional south easterly dip brings higher strata down to the east; and finally, in a faulted inlier at Eggleston Bridge (996233).

The only definite outcrop of the Tynebottom Limestone occurs in the bed of the River Lune. Its exposed thickness (14 feet), and stratigraphical position relative to the Single Post and Cockle Shell Limestones establish its identity. A limestone exposed below the Whin Sill near Crossthwaite Quarry may also be the Tynebottom, but there is no proof of this. Like Yoredale limestones in general, it is a grey or blue-grey crinoidal limestone.

The Alternating Beds, those between the Tynebottom and Scar Limestones, are a series of alternating shales, sandstones and thin limestones amounting to between 110 feet and 190 feet. Two of these thin limestones are persistent, and of widespread occurrence, the lower one being called the Single Post Limestone, the upper one the Cockle Shell Limestone, because of the abundant presence of <u>Gigantoproductus giganteus</u> (Martin). The alternating Beds are well exposed in the banks of the River Lune and in Lunedale Quarries (see pl. 2 , p. 24), and are notable in this locality for the poor development of sandstones and the presence of a number of thin limestones, in addition to the Single Post and Cockle Shell Limestones. The Single Post Limestone crops out in Lunedale Quarries as 9 feet of fine grained, generally muddy, crinoidal grey limestone, with a 10 inch fossiliferous, calcareous shale parting (although the lower post may perhaps be regarded as not forming part of the Single Post proper). The Cockle Shell Limestone as exposed here, consists of 2 feet 6 inches of fine grained grey limestone with a characteristic abundance of giganteid productids, and a prolific microfauna ? also 65 (see p. 61).

An interesting fossil find is that of an internal mould of a coral calyx, probably <u>Cyathaxonia</u> (see p. 60) in a "famped" (replaced by yellow ochre) sandy limestone in a small stream south of East Park (943234). The limestone occurs below the Whin Sill and therefore below the Single Post Limestone (see p. 25). Garwood (1912, 1924) found <u>Cyathaxonia rushiania</u> Vaughan in the shales immediately above the Scar Limestone in Rundale Beck, Westmorland, and a short distance below the Orionastraea Band (base of D3) in Stockdale Beck, Yorkshire. The Orionastraea Band is represented by the Tynebottom - Single Post Limestones (Turner 1927). Turner (1927) records <u>Cyathaxonia</u> from the Scar Limestone in Maize Beck, Westmorland. <u>C. rushiana</u> is reported by D. Hill (1938, p. 6) as being present in C2, D1, and her lower Coral zone 2 (from the base of D2 to the base of the Simonstone Limestone). <u>C. cornu</u>, according to her occurs in Z2, γ, C1, C2, lower Coral zone 2, and zone 3, but not in upper zone 2, (see p. 61).

To the west, on Crossthwaite Common, sandstone becomes more prominent in the Alternating Beds, while variations in thickness and frequency of the limestones also occur. Thus in Rowton Beck the Cockle Shell Limestone has thickened to 9 feet of shaly muddy limestone, but still retains ~~to~~ its characteristic fauna. In addition it has yielded <u>Lithostrotion junceum</u> J. Sowerby. Garwood (1924) found this to be characteristic of the Orionastraea Band of the Settle District. Turner (1927) has recorded <u>L. junceum</u> from horizons ranging from the Lower Little Limestone to the Scar Limestone, being the only abundant form in this latter limestone. Hill records it in Upper Coral zone 2, and zone 3. It also occurred in the Cockle Shell and Five Yard

Limestones of the Roddymoor borehole (Lee 1924, p.147). It has not been found above the Cockle Shell Limestone by the author, and G.A.L. Johnson does not find it above the Five Yard Limestone in south-western Northumberland. He is of the opinion that this represents its probable upper limit (1953, p. 206).

The Single Post Limestone, in Rowton Beck, is represented by but one 3 feet 6 inches to 4 feet thick post of saccharoidal limestone, overlying a 10 feet quartzite, both of which have been metamorphosed by the underlying Whin Sill.

The twin Teesdale Fault lets the Alternating Beds down to the bed of the Tees in the neighbourhood of Scoberry Bridge, where certain changes in the succession occur when compared with Rowton Beck. Sandstones are as well developed, over 21 feet, occurring between the Whin Sill and the Cockle Shell Limestone. The latter, however, has once more reverted to the more normal thickness of 3 feet to 3 feet 6 inches, and consists of fine grained grey limestone with giganteid productids, while the Single Post Limestone is slightly thicker comprising 5 feet of saccharoidal limestone..

The Scar Limestone is well exposed in Bow Lee Beck (see pl. 3A , p.30) and Newbiggin Beck. It varies from 20 feet (in the former) to 24 feet (in the latter) in thickness, consisting largely of fine grained, grey or blue-grey crinoidal limestone, which is locally pyritous. It generally has two or more shale partings of varying thickness, but no more than 8 inches and 2 feet respectively, situated in the top 10 feet or so. The upper shale parting is fossiliferous in most localities, while the lower one yielded some fossils in Bow Lee Beck Quarry. Rayner

(1953, p.286) found Goniatites cf. granosus in the shales above the Scar Limestone in Bow Lee Beck - a low P2 fossil and the lowest record of a P2 fossil in Northern England. The base of the limestone is sandy in Bow Lee Beck, grading down into a fine grained sandstone. The top of the limestone is usually shaly, and succeeded by very fossiliferous shales. The Scar Limestone is not notably macrofossiliferous, but its microfauna is rich and varied. The most notable occurrence is the foraminifera Howchinia bradyana Howchin, which, according to G.A.L. Johnson (1953 p. 218) makes its final appearance in the Three Yard Limestone of Northumberland.

Shales of varying thickness above the limestone are followed by the Low Brig Hazle. This latter reaches its greatest development in Bow Lee Beck, with thicknesses of 30 feet near the quarry, and at least 40 feet in Hell Cleugh to the north. It consists of fine to medium grained sandstone. Compact and generally flaggy (current bedded in its thicker development), it is made up of interlocking, generally angular, quartz grains with occasional plagioclase felspars, and muscovite flakes sometimes arranged in thin regular bands parallel to the bedding. Interstitially, clay minerals occur in patches, but are not abundant. The rock is pyritous in places, and some small tourmalines occur. Interstitial calcite occurs locally. In Newbiggin Beck the sandstone amounts to no more than 25 feet in thickness, while 20 feet of highly micaceous, flaggy, ripple-marked sandstone occurs in the Tees.

Shales and thin sandstones, up to 14 feet thick, separate the Low Brig Hazle from the Five Yard Limestone, a dark grey fine grained, compact limestone, with numerous shale partings, largely concentrated in the lower 7 feet or so. It contains some gigantied productids, but not in the abundance met with in the Cockle Shell Limestone. Apart from occurrences of this fossil in the Great Limestone, it is not recorded above the Five Yard Limestone (see pp. 61-2). The limestone attains a thickness of 16 to 20 feet and is well exposed in Sommerhill Force (see pl. 4A p. 34). It is microfossiliferous.

It is succeeded almost immediately by the High Brig Hazle, a fine grained grey or buff quartzitic sandstone amounting to 40 feet in Bow Lee Beck. It is made up of angular and sub angular quartz grains, many of which show slightly biaxial interference figures (2E up to 4° or 5°) and undulose extinction (this is generally true of all the arenaceous beds examined in thin section in the present area). Cement is generally absent, although some mantles of secondary silica do occur. The sandstone is micaceous in some localities, with muscovite and some hydrobiotite. Felspar is apparently rare, but some clouded albite grains occur. Clay minerals occur interstitially, and on weathered surfaces sometimes give the rock a mottled appearance. Accessor~~ies~~y minerals include zircon, rutile, and tourmaline. At Bridge Sill (962250) it is pyritous.

A 4-inch coaly shale occurring 8 feet above the High Brig Hazle at Mirk Holm in Bow Lee Beck, may be equivalent to the Shilbottle Coal of Northumberland.

The Three Yard Limestone is represented by 6 feet of fine grained, blue-grey, crinoidal limestone in the western part of the area, but further east, in Hudeshope Beck, it thickens, by the development of a lower 18 inches limestone post, totalling

9 feet (see pl. 4B , p. 34). The macrofauna of the limestone is poorly developed, but it is microfossiliferous. Howchinia Bradyana, was not seen.

Calcareous, fossiliferous shales, from 7 to 9 feet thick, with a brachiopod - crinoid - bryozoan fauna succeed the limestone, followed by a limestone which is coarsely crinoidal in places and muddy elsewhere. This limestone varies from 11 feet to 14 inches (thinning to the north) in Hudes Hope, is 12 feet 6 inches thick in Brokersgill Sike to the west, and is probably represented by some black, muddy limestone with shale partings, in Laddiegill Sike still further west. Up to 60 feet of shales with ironstone nodules follow.

The Nattrass Gill Hazle is completely absent in Hudes Hope, south of Snaisgill, but 150 yards north of the mouth of Snaisgill Sike, a 7 feet ganistroid sandstone is taken as representing the incoming hazle. Mine records confirm its development to the north west, 10 feet being recorded in Skears Great Rise, and Skears Mine Vein F. In stream exposures to the west, the hazle is either absent, or poorly developed, as is the case east of Middleton (see p. 44).

The Four Fathom Limestone varies from 10 feet (see p. 51) in thickness west of Hudeshope Beck, to 20 feet in the Eggleston Bridge inlier. It is a grey, crinoidal limestone, generally sideritic, and is frequently slightly stained with limonite on weathered surfaces. Its macrofauna is largely confined to a thin band (up to 6 inches thick) situated 5 feet from the base of the limestone. Rolled clisiophyllids form the bulk of the fauna, with Dibunophyllum bipartitum varieties being dominant. Of these the koninoki type is most prevalent. Gigantoproductus latissimus J. Sowerby is the most common brachiopod. The limestone is microfossiliferous containing, amongst other things "Algae a" Johnson, and Archaediscus karreri Brady ss. The former has been located as far down as the Five Yard Limestone, but reaches its maximum development in the Great Limestone, above which it is unrecorded (see pp.63-4). Johnson (1953 p.218) states that A. karreri dies out above the Three Yard Limestone in Northumberland, Short (1954, p. 122) however records it as high as the Lower Oakwood Limestone on the Pennine Escarpment (see p. 64).

Approximately 40 feet of shales succeed the limestone, poorly fossiliferous, but notable for the presence of Tylonautilus nodiferus Armstrong early mut. Stubblefield in Howgill Sike, denoting a high P2 age (see pp.62-3).

The Quarry Hazle is again poorly developed, being completely absent in Hudes Hope south of Low Skears Mine (947276), where 10 feet of sandstone is present below the Iron Post Limestone. To the north-west it thickens, 30 feet being recorded in Skears Great Rise. Both west and east of Hudes Hope the sandstone is poorly developed until we reach Intake Sike to the east. Here, although it is difficult to assign any single sandstone to the horizon, a total of 21 feet of sandstone, with interbedded shales occurs below the Iron Post Limestone.

The Iron Post Limestone is so-named because of "the hardness of the bed, not from any ferruginous tendancy". (Dunham 1948, p.23). It proves to be a highly variable horizon, ranging from a fine-grained, grey, fossiliferous limestone, to a sandstone which may or may not be calcareous. The limestone may be muddy or sandy, microfossiliferous or non-microfossiliferous. It is locally sideritic. In thickness it varies from 2 to 5 feet.

Succeeding beds are poorly exposed, amounting to approximately 40 feet below the Great Limestone. The sandstone below this latter limestone, the Tuft or Water Sill, is again poorly developed. A northerly thickening is once more encountered in the Hudes Hope area, from 8 feet of medium grained, buff ganistroid sandstone at Low Skears Mine, to 30 feet in Skears Great Rise. Further north west, at least 20 feet of coarse grained grit is referable to this horizon in Blea Gill. West of Hudes Hope the Tuft is poorly developed.

Thus in the case of the Nattrass Gill Hazle, the Quarry Hazle, and the Tuft, we have a fairly rapid northerly or north-westerly thickening in the Hudes Hope - Coldberry Mines area, with poor development to the west and east.

All the persistent limestones are microfossiliferous, with foraminifera forming the greater part of the fauna, but with bryozoans and algae also occurring.

DETAILED STRATIGRAPHY.

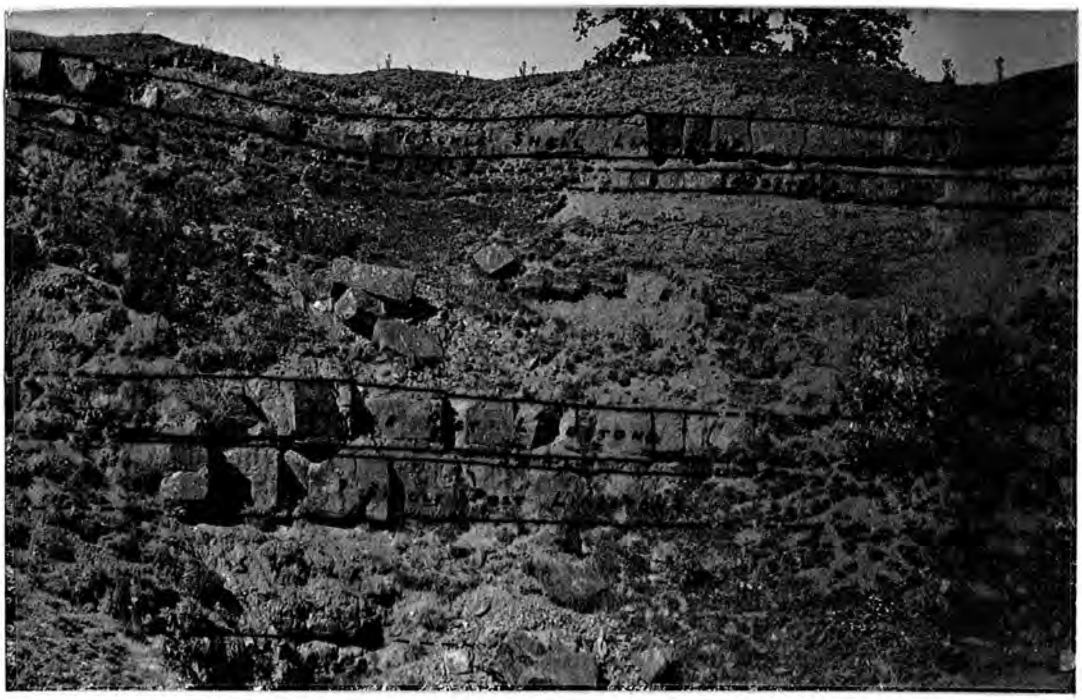
Strata up to the base of the Five Yard Limestone.

Lunedale and Crossthwaite Common - The top of the Tynebottom Limestone is exposed in the core of a small anticline in the bed of the River Lune (953235) where 14 feet of dark grey, coarsely crinoidal limestone, stained with haematite and limonite, and saccharoidal in places, are exposed. Dips off this anticline of 9° to the east, and 10° to the west were recorded. Immediately to the east three old adit levels indicate the presence of a mineral vein (or veins). No faulting or mineralization is seen however (apart from the haematite and limonite staining in the limestone), because of a covering of alluvium and drift in the stream bed and banks. Downstream higher members of the succession crop out so that the vein probably has an easterly downthrow. Solid exposures immediately east of the limestone are poor, but some grey, calcareous, micaceous shales followed by a fine to medium grained micaceous buff sandstone, are exposed, approximately 60 yards downstream, with dips of 5° to the east 20° south, and 14° to the east 60° south. Upstream, approximately 170 yards to the west, and in the stream running from East Park (943234), the following succession is exposed :

	Ft.	Ins.
Buff Shale.	6	0
Black Shale.	0	2
Sandy limestone replaced by ochre.	5	0
Black shale up to	1	0
Fine grained buff sandstone.	5	0
Black micaceous shale.	3	0
Massive fine grained sandstone.	8	0

In the disused Lunedale Quarries (954238), and the banks of

Plate 2.



A section in Lunedale Quarries showing strata from the top of the Whin Sill to the shales above the Cockle Shell Limestone.

the River Lune below (plate 2, p. 24) an excellent section up to, and including part of the Scar Limestone is revealed. Slight variations occur in the details of the succession, but a typical section would be:

		Ft.	Ins.
Grey crinoidal limestone, sandy at the base (part of the Scar Limestone)		17	0
Micaceous ganistroid sandstone		3	8
Limestone with giganteid productids (Cockle Shell Limestone)		2	6
Soft ganistroid sandstone		0	9
Fine grained sandstone, lower 1 ft. shelly.		3	0
Carbonaceous Shale		16	0
Muddy Limestone		0	8
Calcareous Shale		2	0
Muddy fine grained dark grey limestone	Single Post	4	0
Fossiliferous calcareous shale		0	10
Muddy crinoidal limestone		4	2
Baked black shale		5	6
Whin Sill		18	0
Alternating sandy and calcareous shales and fossiliferous muddy and sandy limestones.		20	0

The limestones in the lower 20 feet tend to weather to a yellow famp (i.e. replaced by ochre), but none of them compares in thickness with the previously mentioned 5 feet famped limestone outcropping upstream.

The beds between the Scar and Tynebottom Limestones are known as the Alternating Beds, and were described by Dunham (1948 p. 19) as "comprising shale (the "Tynebottom Plate") succeeded by thin beds of fine grained sandstone, sandy shale, and shale many times repeated......... The series usually includes two thin limestones, the Single Post........ and the Cockle Shell." He also notes that more than two such limestones are present in some localities. In the present area, apart from the 8 feet and 5 feet sandstones noted, the succession is singularly poor in sandstone development, and limestones are very much in evidence. A gap of unknown thickness occurs between the Tynebottom

Limestone and the next exposures of succeeding beds. The easterly exposures are probably downfaulted, while to the west, 160 yards of unexposed ground occurs in strata dipping from 8°-10° in a south-westerly or westerly direction. Some 145 feet of beds are assigned to the Alternating Beds in Ettersgill to the north, and figures quoted by Dunham (1948, p. 19) from various parts of the Northern Pennine Orefield vary from 110 feet - 190 feet. Up to 90 feet of beds are exposed in Lunedale above the Tynebottom Limestone, so that the gap may be estimated as anything from 20 feet to 100 feet.

Dips of 9° east bring the Scar Limestone down to stream level at Lune Bridge (959241) where it outcrops in the stream as a light grey crystalline limestone. It is easily traced through intermittent exposures in both banks of the river and forms the top of the bank west of Westfield House (957239). The Cockle Shell and Single Post Limestones are likewise brought down to stream level below the Scar Limestone. The Scar Limestone outcrop ends short of the postulated position of the northerly branch of the Teesdale Fault.

A north-easterly fault running between Bowbank (946237) and the Lunedale Quarries repeats part of the succession to the north. Thus, 100 yards south of East Park farm house, a famped,(replaced by yellow ochre) slightly fossiliferous limestone, lithologically identical with that downstream (see p. 23) is exposed on the left bank of the stream dipping at 13° to south 28° east. On the eastern end of Limestone Hill, the Whin Sill outcrops, giving place on the west to the Scar Limestone which gives the hill its name.

In Hell Gill (946237) immediately below the Bowbank road a few feet of the Whin Sill, with some overlying shale, are again exposed, while Moss Gill, a dry glacial channel north of the road, is cut through the Scar Limestone. Up to 20 feet of blue-grey crinoidal limestone are exposed, though neither the base nor the top are clearly seen. Exposures are frequent along the northern side of the valley, and at one point (949240) can be seen to dip at 45° to the south east indicating the proximity of the fault. The base of the limestone here lies at about 925 feet O.D. descending to the east, while in Lunedale Quarries, the base lies approximately at 825 feet O.D., again descending to the east. The throw of the fault can therefore be calculated as in the region of 100 feet down to the south-east.

From Moss Gill the Scar Limestone can be traced around Bowbank Fell to some overgrown quarries approximately 300 yards south east of Middleton Quarries (951242), where up to 10 feet of coarse crinoidal limestone is seen. Drift obscures the solid geology westwards for half a mile, with one shake hole the solitary indication of the position of the limestone. Westwards from here along Crossthwaite Common however, partly drift obscured features and intermittent exposures where small streams cut into the features, allow confident mapping of both the Cockle Shell and Scar Limestones for over a mile to Carley Green. Shake holes are more numerous in this tract and serve to confirm the position of the limestones. Both limestones are exposed in two small nameless streams (939245 and 936246) but the first really useful exposure occurs at the head of Oliver Gill (the details of ? Not [illegible] which are seen in fig. 1, p.14, "Carley Green").

The vastly thickened Whin Sill occurs a few feet below the section. The Single Post limestone (or limestones) is here either absent or represented wholly or in part by a 1 foot 9 inches limestone with a shale parting. Features, some limestone exposures, and an old quarry revealing both limestones (926249), allow reasonably accurate mapping westwards to a N.W. - S.E. mineral vein at Carley Green, marked by a line of old shafts. It downthrows to the east, bringing the Whin Sill and an overlying sandstone on the west against the Scar Limestone on the east. East of the fault the top of the Scar Limestone is marked by a feature with exposures of a fine grained flaggy buff sandstone (the Low Brig Hazle) in streams and an old quarry (925245).

Patches of drift complicate mapping of the solid geology for a distance of half a mile to the west, but the Scar Limestone feature allows one to trace the limestone to the first exposures in some tributaries of Willy Brig Sike, where 7 feet to 8 feet of grey crinoidal limestone rests on a fine grained ganister. The top of the limestone is drawn in relation to the Low Brig Hazle feature in which some fine grained flags outcrop, while some poorly fossiliferous shales are seen in a small stream (919248), lying below the sandstone. Westwards from the above mentioned Scar Limestone outcrops, the limestone is readily traced through a feature with almost continuous scar outcrops to Rowton Beck. The beck affords another good section from the top of the Scar Limestone to the Whin Sill (see fig. 1 p. 14). The Scar Limestone amounts to 21 feet overlying a 6 foot ganister, the top 6 inches to 10 inches of which grades up into the limestone. The Cockle

Shell Limestone is very much thicker, totalling 9 feet of shaly, muddy limestone, with giganteid productids, the latter confirming its identify. The succession below is also quite different; sandstone is much more in evidence, while the Single Post Limestone is represented by 3 feet 6 inches to 4 feet of saccharoidal limestone, overlying a 10 feet quartzite, obviously recrystallized by the Whin Sill. The effect of the much thickened Whin Sill is of course far greater here than in Lunedale, but it is interesting to note that the 1 foot 9 inch Limestone in Oliver Gill (p.27) is apparently unaffected. The Cockle Shell Limestone was here evidently formed in muddy water, the high proportion of clastic material probably accounting to some extent for the increased thickness.

To the east, in Easter Beck, the Cockle Shell Limestone is again exposed as 9 feet of shaly, muddy, fossiliferous limestone. No beds are seen below until the Whin Sill, but above, the Scar Limestone is seen overlying a ganister. Drift again obscures the solid geology to the east, but 9 inches of baked fossiliferous shales, identical with those seen below the Cockle Shell Limestone in Oliver Gill, crop out in a tributary of Willy Brig Sike, a few yards south of Water Race (914254) and serve to fix the positions of the Cockle Shell and Scar Limestones fairly accurately. ? [illegible]

Below the Whin Sill, immediately south of the southerly branch of the Teesdale Fault, a few exposures of country rock are seen. In Oliver Gill, some fine grained massive grey sandstones outcrop, occurring somewhere within the Alternating Beds. Just over 300 yards to the north west below Crossthwaite Quarry

(929254) a few feet of massive altered limestone outcrop. It is a heavy dark to medium grey crystalline limestone with calcite veins and clusters of small reddish brown garnets. It may be part of the Tynebottom Limestone, but this is purely conjectural. A mile to the north west in Mill Beck, some altered grey shales over 18 feet of flaggy grey, buff sandstone with some carbonaceous streaks are seen below the Whin Sill.

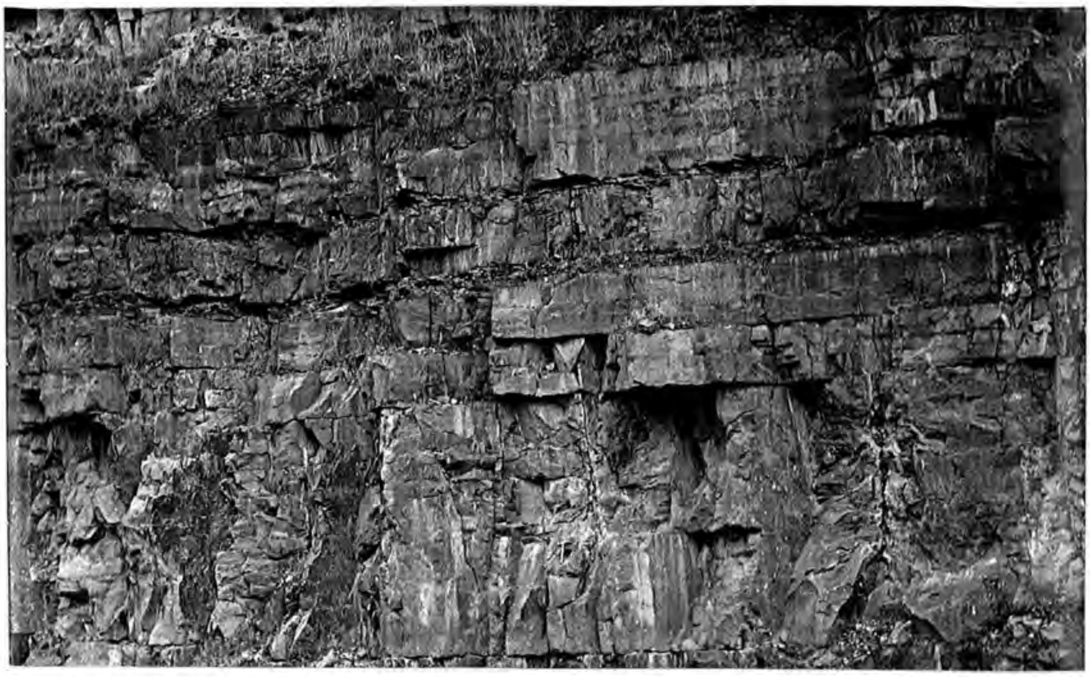
Teesdale. - The twin Teesdale Fault, running in a north-west - south-east, direction, with both members downthrowing to the north-east, carries the Alternating Beds down to the bed of the River Tees in the neighbourhood of Newbiggin. Thus in the river bed and banks near Scoberry Bridge (911274), the Whin Sill is overlain by :

Whin Sill [illegible]

	Ft.	Ft.	Ins.
Baked Shale.			
Fossiliferous limestone (Cockle Shell)	3 -	3	6
Baked shale grading laterally into a 4 feet sandstone.	3 -	3	6
Sandstone.	6 -	7	0
Baked Shale.		3	0
Saccharoidal limestone (Single Post).		5	0
Fine grained sandstone.		5	0
Baked Shale.		4	0
Ripple-marked sandstone.		9	0

Dips of up to 7° to south east were recorded on the limestones and shales. Sandstone is here again predominant, but the Cockle Shell Limestone has reverted to a more normal thickness than that met with in Rowton Beck. Here again the Single Post Limestone has been completely recrystallized to form a saccharoidal limestone and is slightly thicker than in Rowton Beck. At a higher level in the right bank of the Tees, up to 11 feet of shales and sandstones are exposed in the mouths of three old

Plate 3.



A. The Scar Limestone, Bow Lee Beck Quarry. The base of the Low Brig Hazle is just visible, about four feet above the top of the limestone.

B. A normal fault exposed in the Scar Limestone, Bow Lee Beck. The throw of the fault is approximately ten feet to the north, bringing the top of the limestone on the north(left) near the base of limestone on the south. On the downthrow side the limestone directly overlies a sandstone of which about two feet can be seen.

levels, nearly 8 feet of which consists of sandstone. An old quarry to the south east (912272) reveals a poor exposure of limestone referable by its position to the Scar Limestone. Apart from poor intermittent exposures of up to 3 feet of limestone resting on a compact buff sandstone in the left bank of the lower reaches of Bow Lee Beck, the Cockle Shell Limestone is not seen again in the area.

Several good sections of the Scar Limestone are available in Bow Lee Beck to the north. The first occurs below the old Bow Lee Bridge (908282), where up to 20 feet of blue-grey, fine grained, locally pyritous limestone outcrop in the stream. Shale partings of 1 inch and 2 feet are situated 4 feet and 9 feet 6 inches respectively, below the top of the limestone. The limestone is well jointed in two directions: north 30° west and north 68° east. The Scar Limestone is upfaulted to the north, and a large quarry (plate 3A, p. 30) affords an excellent section in conjunction with the stream. 20 feet of blue-grey crinoidal limestone are exposed, shaly and muddy at the top, and with two shale partings of 6 inches to 8 inches and 1 foot to 2 foot situated about 3 feet and 6 feet respectively below the top of the limestone (the lower parting being fossiliferous). It is succeeded by black shale varying in thickness from 4 feet to 13 feet, the lower 2 feet or 3 feet being fossiliferous. Above, part of a thick, fine-medium grained, current bedded sandstone is seen in the quarry. In the stream bed, the Scar Limestone is seen to grade down into a grey fine grained ganister in its lower 2 feet 6 inches post, and below this a thin shale parting separates it from some thin sandstones and sandy shales.

Three small faults cross the stream near the quarry in an easterly direction. The northernmost downthrows 10 feet to the north bringing the top of the Scar Limestone on the north, near to its base on the south, causing a waterfall. The other two faults throw down a few feet to the south, crossing the stream 36 yards, and 200 yards downstream from the waterfall. Small mineral veins consisting mainly of calcite also occur, while a 3 feet wide zone of brecciated sandstone fragments sandstone in quartz runs north east across the stream above the falls. Horizontal slickensides, are seen in association with this brecciated zone, one case showing a striated and polished limonite surface. Dunham (1948, p.74) has mentioned similar phenomena "suggesting that small movements have occurred since the orebodies have been brought within the zone of oxidation by erosion of the cover." Above the falls, up to 30 feet of current bedded, fine to medium grained sandstone the Low Brig Hazle, is exposed in an old quarry (907285). This outcrops in the stream bed and banks for over 300 yards to Sommerhill Force, where it is followed by 14 feet of alternating sandstones and sandy shales in Gibson's Cave (910286), which is cut out behind the fall, below the succeeding Five Yard Limestone.

Approximately 400 yards to the north, at Mirk Holm (908293), near the confluence of Wester Beck with Bow Lee Beck, the top 12 feet of the Scar Limestone, with a 16 inch fossiliferous shale parting is again seen, upfaulted against the High Brig Hazle. The line of the fault is occupied by a bifid member of the Cleveland Dyke System. 5 feet to 10 feet shale, fossiliferous at the base, separates the limestone from the Low Brig Hazle, which here comprises at least 40 feet of massive, current bedded medium grained sandstone. The Low Brig Hazle forms the valley floor and sides of the lower part of Hell Cleugh, and is succeeded by 8 feet to 10 feet of interbedded shales and sandstones below the Five Yard Limestone. North of the Mirk Holm fault (which downthrows approximately 75 feet to 80 feet to the south) in Wester Beck, the Scar Limestone is once more exposed, showing two well developed joint directions: north 22° West and north 75° east.

To the east, thick drift conceals the solid geology until we reach Newbiggin Beck where the Scar Limestone outcrops again. 24 feet of massive grey crinoidal limestone, pyritous in parts, is exposed below the bridge near Newbiggin School (914278). It contains an 11-inch fossiliferous, calcareous shale parting 4 feet 6 inches from the top, and the upper 2 feet of the limestone are shaly. It is succeeded by 4 feet of fossiliferous shale, and 11 feet of tough massive sandstone. A gap in the succession then occurs and we next see 9 feet of sandstone, shaly in places, followed by 9 feet of black shales and sandstones below the Five Yard Limestone. The gap amounts to no more than 5 feet or 6 feet so it appears that there is a somewhat condensed sequence, probably affecting the Low Brig Hazle. An alternative possibility is the presence of a fault in the gap, possibly representing the continuation of one or more of the small faults seen and inferred in Bow Lee Beck near the quarry (although a reversal of throw is necessary). There is no structural evidence for such a fault. Dips of 4° - 5° to the South-East occur, but these are consistent with the general dip encountered in this locality. It seems best therefore, to invoke a condensed sequence as the true explanation.

No full exposure of the Scar Limestone is again seen, but the top few feet do outcrop in two localities in the bed of the Tees. The first exposure is below Unthank Bank (918263) immediately north of the northerly branch of the Teesdale Fault. Here, a few feet of shaly, muddy, highly crinoidal limestone dip north east at 30° into the river from the fault. Above, calcareous shales passing up into fossiliferous black shales outcrop in the bank for about 150 yards to the north after which drift covers the solid geology. The limestone could possible rise, beneath the drift, to link up with the Scar Limestone exposed in the old quarry near Scoberry Bridge, but this is very unlikely. A north ~~west~~ east - south ~~east~~ west fault downthrowing to the south east has been mapped just west of Miry Lane and there cuts the Scar Limestone. It probably extends to the south west to meet the Teesdale Fault, though drift and alluvium preclude proof.

The final exposure of the limestone is in the Tees a few yards upstream from Crook Pool (931259) where up to 10 feet of blue-grey pyritous limestone shaly at the top, are seen, with calcareous shales 3 feet from the top. The exposure occurs in a gentle dome with dips in the region of 3° to 4°. Above the limestone are 20 feet of black shales, very fossiliferous immediately above the Scar Limestone, and displaying ripple marks. The overlying Low Brig Hazle, best exposed near Breckholm Pool (940255), is at least 20 feet thick and consists of fine grained, flaggy, micaceous, ripple marked sandstones with worm trails and containing some thin sandy shale partings. Dips on the sandstone vary from 10° - 12° to the south east, but on the right bank of

Plate 4.

A. The Five Yard Limestone, Gibson's Cave. The limestone overlies **fourteen** feet of alternating shales and sandstones which are being more rapidly removed to form the cave. The shale partings within the limestone are well displayed.

B. The Three Yard Limestone, Hudeshope Beck. An upper six feet of limestone is separated from a lower eighteen-inch post by four inches of fossiliferous shale. This lower post is not developed over the area in general.

the Tees (935254), the northern branch of the Teesdale Fault is marked by a sharp increase in the dip to 45° downstream.

The Low Brig Hazle is capped by 15 feet of sandy black shales with ironstone nodules, dipping downstream at 5° below the Five Yard Limestone.

Strata from the Five Yard Limestone to the base of the Four Fathom Limestone.

The Newbiggin Area. - The Five Yard Limestone, up to 20 feet thick, is exposed in Bow Lee Beck in Sommerhill Force (plate 4A, p. 34). It forms a resistant ledge over which the beck plunges approximately 20 feet - 25 feet, excavating the underlying shales and sandstones to form Gibson's Cave. The lower 7 feet of the limestone has numerous shale partings up to 6 inches thick, but the remaining 13 feet is more massive and contains some giganteid productids. Downstream the limestone outcrops on top of both sides of the valley, and can be traced into Causeway Sike where the fine grained grey limestone again forms waterfalls, but of much smaller scale. In Causeway Sike 16 feet of limestone with shale partings are exposed, and giganteid productids are again present. The limestone is jointed in three directions: north 25° west, north 85° east, and north 68° east. The outcrop in Bow Lee Beck dies out short of the previously mentioned fault in Bow Lee Beck downthrowing 10 feet to the north (p. 31).

North of Sommerhill Force the limestone floors the beck for a few yards and then gives way to the High Brig Hazle, no shales being seen. The sandstone is tough, fine to medium grained, massive, and current bedded (with no constant directional quality)

Summer of 22'

? loc.

with up to 20 feet being exposed. Exposures are not very good, but approximately 300 yards upstream, 6 feet of blue-grey slightly crinoidal limestone, the Three Yard Limestone, overlying sandstone, outcrops high up on the valley sides. These outcrops can be traced upstream for 300 yards until interrupted by the roughly east - west Lodgesike - Manorgill Vein, here downthrowing 46 feet to the south (Dunham, 1948, p.300). In the stream bed, a zone of mineralized sandstone up to 70 feet wide is exposed in the stream. The sandstone is the High Brig Hazle and faulted against some spotted light grey shales dipping north 20° east at 8° below the Five Yard Limestone. The limestone here consists of 19 feet of medium grey limestone showing no lithological differences from the downstream exposure. The outcrop crosses the stream in the bend approximately 50 yards south of the Wester Beck/Bow Lee Beck confluence, dipping west of north at 7° to 10°. A cliff face just east of the confluence, in the left bank of Bow Lee Beck, affords a good section up to and including the Three Yard Limestone:

	Ft.	Ft.	Ins.
Fine grained, blue-grey limestone.		6	0
Fine grained sandstone.		3	0
Sandy grey shale.		3	0
Fine grained grey (buff weathering) ganister, pyritous in places.		1	6
Silty grey shale.		1	0
Sandstone.		1	0
Shaly sandstone.) Sandy shale.) Black carbonaceous shale.) Coaly shale, 4 inch.)		3	0
Tough cream and grey ganister.		3	0
Grey sandy shale.		2	0
Shaly medium grained grey sandstone.		3	0
Fine grained grey and buff quartzitic sandstone.	30	- 35	0

A small gap in the succession between this section and the

-underlying Five Yard Limestone is probably entirely made up of sandstone (some of which is exposed in the stream) so that the total thickness of the High Brig Hazle here is around 40 feet. From this cliff, the Three Yard Limestone can be mapped through intermittent exposures on the eastern side of the valley, down to the Lodgesike - Manorgill Vein, and northwards for a short distance to the north west - south east fault at Mirk Holm. ? loc
Dips on the High Brig Hazle of 7° to east 6° south were recorded in the cliff face, and stream bed. The Three Yard Limestone also outcrops above Wester Beck in the right bank, south of the above mentioned north west - south east fault.

Dunham (1948, p.21) records a coal 8 inches to 1 feet 4 inches thick which has been worked above the High Brig Hazle in the Langdon Beck area, and suggests that this, together with a ? loc 7-inch seam recorded at Bentyfield Mine, near Garrigill, in the ? loc same position, may possibly be correlated with the Shilbottle Coal of Northumberland. Stanley Smith (1912) classes the coal below the Three Yard Limestone as one of the thickest in Upper Teesdale. At Ashgill Lead Mine it lies near the limestone and is only ? loc 6 inches thick, but its thickness and the thickness of beds between it and the limestone increase to the east, reaching, it is reported, its maximum near the head of Cut-throat Sike, about a mile east north east of Grasshill House, where it has been worked. ? loc It was also worked at Hawke Sike Hush south west of the house, as well as in a series of short levels in the west and south sides of the Three Pikes, where the total thickness, including shale partings is 1 feet 10 inches. It was worked at Barney Gill, just ? loc north of Valance Lodge, where it was reputedly 1 feet 4 inches ? loc thick and separated from the overlying limestone by 5 feet shale. Finally, he states it is only 9 inches thick in Ettersgill Beck ?, loc and separated from the Three Yard Limestone by 5 feet of shale and an overlying 20 feet sandstone.

The 4-inch coaly shale seen in the cliff face at Mirk Holm probably represents the same horizon as that mentioned by Dunham and Smith, though the latter does not make clear the position of the coal in each case, except that it is below the Three Yard Limestone. The Ettersgill Beck coal is probably not the same horizon, occurring below what appears to be the High Brig Hazle. In this connection, however, Dunham (1948, p.21) reports the latter sandstone as being 40 feet thick in Ettersgill Beck, so that Smith's 20 feet sandstone may lie above the High Brig Hazle.

North of the Mirk Holm fault, the Five Yard Limestone outcrops in Hell Cleugh and rises southwards up the precipitous valley ? loc sides. It amounts to 18 feet of fine grained blue-grey limestone with fewer shale partings than at Sommerhill Force, but one is 9 inches thick and fossiliferous. The top 2 feet is shaly. Above the limestone some 18 inches of calcareous shale occur followed by the High Brig Hazle of which 15 feet of fine grained slightly micaceous sandstone is exposed. Exposures north of this are poor, including some black micaceous shales capped by fine grained sandstone in an old quarry near the mouth of Bleagill Sike (909298).

Three mineral veins are exposed in the sandstone in the stream bed, and all have been worked for lead. The first is seen a few yards upstream from the point where the top of the Five Yard Limestone crosses the stream, and is marked by levels on both sides of the beck. Galena and quartz are seen in a vein up to 3 inches or 4 inches wide crossing the stream running north 60° east. Some pyrite occurs in the limestone near the vein. The second vein, again marked by an old level, runs in a parallel direction, and is exposed as an 8-inch to 9-inch vein with galena, calcite and some quartz, crossing the stream below a footbridge approximately 40 yards north of the first one. A further 75 yards upstream the third vein, running in an east - west direction crosses the beck as a vein of calcite with no galena in evidence. It has been worked by levels in both banks of the beck.

Beneath Bleagill Bridge (912299), approximately 250 yards to the east, the Iron Post Limestone (here represented by a grey calcareous sandstone) is exposed at the approximate level of the Three Yard Limestone, so that between the old quarry near the mouth of Bleagill Sike, and the bridge, a fault must run with an easterly downthrow of anything up to 120 feet or more.

Thick drift extends over the ground between Bow Lee Beck and Newbiggin Beck, but in the latter stream the Five Yard Limestone to Three Yard Limestone sequence is once more revealed. In a quarry 150 yards north, north east of the School (915279), the Five Yard Limestone, 16 feet of fine grained crystalline limestone muddy at the base, is separated from the High Brig Hazle (of which 11 feet is exposed), by 4 feet 6 inches of fossiliferous, black, micaceous shale. 400 yards upstream, 6 feet 6 inches of medium grained, crystalline limestone, the Three Yard Limestone outcrops, dipping east 10° south at 3° over some sandstone and carbonaceous shale. Of the remainder of the succession nothing is exposed.

Intermittent limestone exposures enable fairly accurate mapping of the Three Yard Limestone along the valley sides, and above Newbiggin, a feature which is probably the Three Yard, runs south east to Miry Lane, where it is interrupted by a north easterly fault downthrowing to the south east. x

Is this the fault of p. 33?

To the north, in Laddiegill Sike (919291), the Lodgesike - Manorgill Vein throws up part of the sequence to the north. Some black, muddy limestone with black, micaceous shale partings, crops out in the stream 80 yards west of the Four Fathom Limestone. The latter dips east, north east at 15° at approximately 20 feet to 25 feet above the muddy limestone. With the information available (dip, vertical interval, and distance between exposures) it can be calculated that the two limestones are between 70 feet and 80 feet apart, but nothing is seen of the intervening strata through the drift and mine debris of Red Grooves Lead Mine (924291).

East of the Miry Lane fault, drift obscures any feature that the downthrown Three Yard Limestone might form between the fault and Brokersgill Sike, where 6 feet of blue-grey crinoidal limestone crop out. The limestone, resting on 3 feet of fine grained micaceous buff sandstone, is succeeded by 8 feet to 9 feet of calcareous shale passing up into 10 feet of muddy, shaly limestone followed by a dark crinoidal limestone, 2 feet 6 inches thick. Above these beds, a gap of at least 25 feet occurs, probably occupied by shales, and then the following succession is encountered below the Four Fathom Limestone

	Ft.	Ins.
Fire clay.	1	0
Black shale.	0	6
Massive, medium grained, micaceous sandstone.	7	0
Sandy grey shales & sandstones.	7	0

The shaly muddy limestones are lithologically very similar to the Laddiegill Sike occurrence, except that the shale partings in the latter are more definite. Stanley Smith (1912) asserts that an underclay is almost always found immediately below the Four Fathom Limestone and goes on to claim that above High Force it is rarely accompanied by any true coal, though in the country to the south there is a seam, which at Bordale Colliery attains a thickness of 2 feet. The underclay is here represented by a 1-inch fireclay, but no coal exists as one might expect from Smith's assertions. The 7 feet sandstone is our first glimpse of the Nattrass Gill Hazle. The 21 feet or so of calcareous shales and limestone above the Three Yard Limestone indicates relatively prolonged marine conditions in this locality, the significance of which will be discussed later (p.356).

In Owl Gill and Stony Gill to the east, the Three Yard Limestone is not exposed. Below the Four Fathom Limestone, only 18 inches of ganistroid sandstone and up to 15 feet of sandy black shale, fossiliferous in parts, underlain by a pinkish quartzite are exposed. In Stony Gill (931264), this quartzite dips almost due south at 12°, as opposed to a south easterly dip of 3° 80 yards upstream. Moreover, the quartzite appears to dip directly into shales, and the only feasible explanation is the presence of a fault. This fault, which has been mapped in a south easterly direction to the mouth of Hudeshope Beck, and they [illegible] would account for the absence of the Three Yard Limestone in these streams if the downthrow were to the north east.

Further evidence for this fault occurs in the Tees near the mouth of Hudeshope Beck. In the mouth of Crossthwaite Beck, and both banks of the Tees eastwards for over 300 yards, and in the north bank for 300 yards to the west, part of the Five Yard Limestone is exposed dipping at 7° to east 30° south near Breckholm Pool, and changing to 4° to north 60° east near the Crossthwaite Beck/Tees confluence to the east. 8 feet of fine grained grey limestone with a thin, black shale parting, and containing giganteid productids, are seen resting on shales; 30 to 40 yards east of the final limestone exposure, medium to fine grained, current-bedded sandstone, up to 14 feet thick, crops out in the vicinity of the Tees/Hudeshope Beck confluence. Approximately 10 feet of the Five Yard Limestone appear to be missing, while the base of the sandstone, the High Brig Hazle is not exposed. It seems reasonable, therefore, to invoke a fault, downthrowing to the north-east at least 10 feet, to explain this. If this proposed fault is linked up with that seen in Stony Gill, we have a north west - south east fault running in a parallel direction with the twin Teesdale Fault, and throwing in the same direction.

Hudeshope and country to the east. - As mentioned previously, the High Brig Hazle is down faulted at the mouth of Hudeshope Beck. Upstream from here, two fault crossing the stream repeat the succession giving valuable sections of the succeeding strata up to the base of the Four Fathom Limestone. The top 14 feet of the High Brig Hazle, which becomes micaceous in the upper part, outcrop at the mouth of the beck and along the north bank of the Tees for at least 150 yards downstream. Above the High Brig Hazle the following succession is exposed in the beck up to Hude Bridge (946257) :-

	Ft.	Ft.	Ins.
Dark grey limestone.) Sandy, micaceous, grey limestone)		10	0
Calcareous, fossiliferous black shale.		7	0
Medium grey, crystalline limestone.	6 -	7	0
Muddy limestone with nodular structure		0	2 - 3
Grey ganister.		2	3
Sandy micaceous shale.			

The 10-feet limestone and calcareous shale above the Three Yard Limestone compares with the succession in Brokersgill Sike (p. 39) except that the limestone is far less muddy and shaly. The Three Yard itself seems to be maintaining both its thickness and lithological characteristics, though the thin "nodular" limestone below is a new feature. The Three Yard Limestone can be traced to the east by means of a feature running to Town End (951253), where it meets a north west - south east fault downthrowing to the south west. This fault crosses Hudeshope Beck approximately 30 yards upstream from Hude Bridge and throws the Three Yard Limestone up to 60 feet to the north east. Beds from the High Brig Hazle, 10 feet to 12 feet of which are exposed, up to some fossiliferous, calcareous black shales above the Three Yard Limestone are once more exposed. The details of the succession are very similar to those downstream except that the thin limestone below the Three Yard does not occur. No coal was seen in any of these sections below the Three Yard Limestone.

North of the fault the beds dip at 3° to the South east. The Three Yard Limestone can be traced upstream to the second fault, Holm Head Vein, a mineralized fault running north east - South west and downthrowing 10 feet to the South west. Various changes in the succession occur upstream from the vein. A 4 inch coal, tough and compact, veined with streaks of calcite and containing patches of limonite, overlies a 10 inch ganister 7 feet below the Three Yard Limestone. This is probably equivalent to the coal met with in Bow Lee Beck (p.35). The Three Yard Limestone itself is thicker, a 1 feet 6 inches post of grey limestone occurring below it separated from it by 4 inch of fossiliferous shale (plate 4B p. 34). This is not met with outside Hudeshope Beck. The thin "nodular" limestone seen downstream may possibly be a poor development of the same horizon.

When traced upstream from Holm Head (947261) striking changes occur above the Three Yard Limestone. At Holm Head, it is capped by 6 feet of black fossiliferous shales, a 3 feet limestone with shale partings, shale varying from 10 inches to 0 inches and finally, an 11 feet grey limestone which is shaly in places and coarsely crinoidal in others. 100 yards upstream the following succession is seen above the Three Yard Limestone:-

	Ft.	Ins.	Ins.
Grey limestone sandy at the base.	6	0	
Black shale.	0	9	
Limestone.	0	10	
Sandy, micaceous shale.	1	0	
Limestone.	0	4 -	6
Sandy, micaceous shale.			

The limestones are obviously giving way to shales. Further upstream this facies change is developed, the limestone becoming attenuated with shale intercalations thickening and replacing the limestone, until just under quarter of a mile north of Holm Head, only one 15 inch limestone remains, forming a small anticline in the stream bed with dips of 15° to the south west and 5° to the north east off its flanks. Upstream the limestone is succeeded by black, calcareous shales with 1 inch to 2 inches lenticular bodies of very fossiliferous, shaly, muddy limestones. The bulk of the organic debris consists of crinoid material. These beds grade upwards into black, silty shales with ironstone nodules, and with two thin limestone bands situated 20 feet and 25 feet below the base of the overlying Four Fathom Limestone. The shales total approximately 65 feet to 70 feet. Immediately below the Four Fathom Limestone, as exposed in Snaisgill (948268), lies a 3 feet 6 inches fireclay, but no coal occurs. The beds dip almost due east at 5°. A conspicuous feature of the Hudeshope succession so far is the complete absence of the Nattrass Gill Hazle. Approximately 150 yards upstream from the mouth of Snaisgill Sike, 7 feet of ganistroid sandstone overlie 4 feet of sandy, micaceous black shales with some large plant remains, a 1 foot sandstone and some black shales. Contact with the overlying limestone is not seen, but in the opposite (right) bank of the stream, the Four Fathom Limestone overlies a fireclay capping shales. This 7 feet ganistroid sandstone is probably the Nattrass Gill Hazle, coming in upstream. No further surface outcrops occur to amplify the picture, but mine records testify to the incoming of the Nattrass Gill Hazle to the north, or north west, 10 feet being recorded in Skears Great Rise, and Skears Mine Vein F (fig. 1, p.14).

As stated by Dunham (1948, p.22), the Nattrass Gill Hazle is poorly developed in Harwood and Upper Teesdale, and is almost wholly represented by "grey beds" in some sections. It was seen to be 7 feet thick in Brokersgill Sike, overlying 7 feet of shaly sandstones and sandy shales (grey beds).

The development of the Nattrass Gill Hazle and the supra - Three Yard limestones is obviously linked in some way. It is not suggested that the limestone, and Nattrass Gill Hazle are contemporaneous, as is disproven in the Brokersgill Sike section, but it is suggested that the distribution of these beds provides critical evidence concerning the conditions under which these beds were laid down (but see p.356).

As previously stated, the High Brig Hazle is exposed east of the Hudeshope Beck/River Tees confluence for a distance of up to 150 yards. Beyond this it is lost sight of until it outcrops in the bed of the Tees for over 350 yards, south west of Leekworth (959249). 12 feet of tough, current-bedded, medium grained, cream sandstone, with some calcareous cement is exposed, dipping east south east at 3°. To the south, a small knoll-like feature (960246), reveals some fine grained grey limestone (probably the Three Yard Limestone) dipping north at 25° apparently, although the nature of the outcrop is such that the dip reading is not very reliable.

The High Brig Hazle is faulted out at Rowantree Bank by what is probably a continuation of the north west - south east fault seen north of Hude Bridge. The downthrow of the fault at this point is to the north east however, the south westerly downthrow in Hudeshope being due to an east-west fault north of Laky Hill (961248) which downthrows to the south, and joins the first fault to the west of Laky Hill. Between these faults, the Great Limestone has been let down to form the Laky Hill outlier. North of the east - west fault, at Bridge Sill, the High Brig Hazle again crops out at river level, lithologically identical with previous exposures, dipping east south east at 8°. It totals 18 feet here, but once more the base is not exposed.

Thus the only full thickness seen in the area is in Bow Lee Beck where the total of 40 feet is probably abnormally thick. The sandstone is exposed at river level on either side of the twin fault so that the respective northern and southern downthrows are roughly equal, in the region of 150 feet or more. The northern downthrow is probably slightly greater however in view of the fact that a greater thickness of the High Brig Hazle is seen to the north, and the Great Limestone dips steeply (18°) towards the northern fault. Thus the combined effect of the two faults is probably a slight southerly (or south westerly) downthrow, increasing to 60 feet in Hudes Hope.

Above the sandstone at Bridge Sill, loose material obscures the solid geology, but some fine grained grey limestone probably part of the Three Yard Limestone, is exposed in the right bank of the Tees, 100 yards downstream. Black shales containing ironstone nodules and a few fossil fragments outcrop along the northern banks, but their thickness cannot be measured because of the dip and nature of the exposures.

Some interbedded shales and calcareous sandstones crop out below the Four Fathom Limestone near the mouth of the stream east of Howgill Sike. No significant development of sandstone referable to the Nattrass Gill Hazle is seen along the banks of the Tees below Bridge Sill. While there are some gaps in the succession, none are of any significant thickness so that one must conclude that the hazle is absent, or but poorly developed.

The final exposure of these beds in Teesdale, occurs in a faulted inlier at Eggleston Bridge (996233), where the following succession is seen below the Four Fathom Limestone :-

	Ft.	Ins.
Black carbonaceous shale.	5	0
Coaly shale.	0	1
Quartzite.	0	7
Ganistroid sandstone.	1	0
Sandy shale and shaly sandstone.	8	0

The 1 inch coaly shale is probably equivalent to the coals referred to by Stanley Smith (1912) as existing below the Four Fathom Limestone, but hitherto not seen in this area. The Nattrass Gill Hazle, or part of it may be represented by the lower 8 feet or 9 feet of this succession. No older beds are revealed.

Lunedale - Old quarries with some poor exposures of medium grained buff sandstone below the Four Fathom Limestone feature north of West Pasture Road, establish the presence of the Nattrass Gill Hazle hereabouts.

Beds from the base of the Four Fathom Limestone to the base of the Great Limestone.

Newbiggin area. - The Four Fathom Limestone is first met with near the head of Laddiegill Sike, west of Red Grooves. The combined effects of faulting and debris from hushing and mining activities detract much from the value of the stream section. On the 1250 feet contour a massive, limonite - stained, crystalline limestone outcrops, dipping east north east at 15° below black micaceous shales. The limestone is shattered in places under the influence of a west north west - east south east vein, downthrowing to the south, which crosses the stream near this point. The Four Fathom Limestone is repeated immediately north east of the fault dipping at 45° in directions varying from north north east to east north east. The crinoidal nature of the limestone is more in evidence in these exposures. Between this limestone and the Great Limestone the beds are obscured by debris and only a few feet of micaceous black shales overlying the Four Fathom Limestone are seen. No extensive mineralization is seen, the fault being classed as a 'vein' on the evidence of the limonite staining of the limestone on the southern side of the fault.

To the north east in Bleagill Sike, the Iron Post Limestone is revealed 130 yards upstream from Bleagill Bridge. 3 feet of dark grey limestone, weathered on the surfaces to a yellow-brown famp, crops out in the stream bed. It is well jointed in two directions : north 73° east and north 30° west. Below the bridge, the limestone has given way to a grey, calcareous sandstone overlying some black micaceous shale. Lower members of this part of the succession are not seen due to the presence of the fault mentioned previously (p. 38), throwing up older beds, near the horizon of the Three Yard Limestone, to the west. Upstream, near Bleagill Mine (916303), 20 feet of coarse grained, part massive, part flaggy grit, or sandstone, the Tuft, dips east south east at 35° below the Great Limestone. A feature which contains the Tuft, and probably some underlying shales, emerges through the drift to run to Bleak Ley Green Hush and another hush to the south east, in both of which the Tuft is revealed as a
closely resembling the of
massive fine grained sandstone, the lithology being more normal for a Middle Limestone Group sandstone.

The feature is lost to the north of Bleagill Sike, but in Bales Hush, at its south western extremity, the Iron Post Limestone outcrops as a fossiliferous fine to medium grained quartzitic sandstone, 2 feet 6 inches thick. Nothing is seen in situ between this and the Great Limestone, an estimated 40 feet above, but the abundance of loose blocks of medium grained sandstone testifies to the presence of a well developed Tuft.

For our next exposures we must go to Ravelin Gill and Brokersgill Sike, although a feature running through High House (917280) below Stable Edge, may possibly represent the Four Fathom Limestone. In these streams the Four Fathom limestone is represented by 10 feet of fine grained, crinoidal limestone, overlying a 1 foot soft ganistroid sandstone. The Ravelin Vein, running east north east and downthrowing 6 feet to the north west (Dunham, 1948, p.302) cuts the limestone 30 to 40 yards north of Brokersgill Sike. The vein is not seen at the surface at this point but its position is approximately indicated by an old level driven in shales above the limestone, which worked the vein. South of the vein, the limestone dips due east at 3°.

A gap of 40 feet or so follows the limestone before the next exposure in Brokersgill Sike, the gap probably being occupied by shales. We then meet the following succession :

		Ft.	Ins.
Dark, grey, muddy, crinoidal limestone.	The Iron	2	0
Dark limestone, sandy towards the base.	Post Lst.	2	10
Ganister, shelly in places.		2	0
Black, limonite stained shales.			

Below the Iron Post Limestone, here almost 5 feet thick, the Quarry Hazle is represented by only 2 feet of ganister, presumably any significant development of sandstone below the shales would outcrop in the stream. On the other hand one might regard the shelly ganister as an integrel part of the Iron Post Limestone, especially bearing in mind the sandy base of the limestone proper, and the sandy development of the limestone elsewhere. In this case, the Quarry Hazle is absent. Another gap of 10 to 15 feet occurs before we encounter some limonite-stained black shales.

These are followed by 4 feet of soft, sandy, micaceous fireclay, and a 1-inch coal smut below the Great Limestone, the lower 12 inches of which is sandy. A coal smut is commonly found below the Great Limestone (Dunham, 1948, p.25). The significant factors about the succession as revealed in this stream section, are, firstly, the very poor development (or absence) of the Quarry Hazle; and secondly, the absence of the Tuft which was at least 20 feet thick in Bleagill Sike. The fireclay (which may possibly be regarded as the local development of the Tuft), is shaly in parts, and banded, with alternating yellow and black carbonaceous bands approximately 1/4 inch thick. The significance of this banding is not clear, it may represent a seasonal variation of sediments supplied, or a seasonal, poorly developed vegetation. In view of the extreme thinness of the yellow, sandy layers, it seems highly unlikely that they could support vegetation, and there are no signs of rootlets. Probably, the dark bands represent influxes of finer grained, muddy material with a high carbonaceous content.

Drift partly obscures the solid geology between Brokersgill Sike and Owl Gill, but a feature, which has been mapped as the Four Fathom Limestone, can be picked up 300 yards to the south east, and runs part of the way. In Owl Gill, the Four Fathom Limestone consists of 10 feet of dark grey crinoidal limestone over an 18 inch sandy fireclay. The overlying beds are not exposed in one continuous section, but an estimated total of 35 to 40 feet of black silty shales can be seen, followed by a soft, micaceous, sandy fireclay below the Iron Post Limestone. Here, the 'limestone' is represented by 2 feet of medium grained calcareous sandstone. No further exposures occur below the

Great Limestone.

A slight dip in the strata to the south east is reflected in the relation of the Four Fathom Limestone to the contours in Owl Gill and Stony Gill, descending from 875 feet O.D. in the former to 825 feet O.D. in the latter. A dip of 3° south east was recorded in the shales below the limestone in Stony Gill. In this gill, the Four Fathom Limestone is again 10 feet thick and consists of light grey crinoidal limestone. No contact with overlying beds is seen in these various stream sections, so that the top of the limestone, and consequently its full thickness, is not fixed with certainty. The fact that 10 feet has been recorded in all sections may mean that this is the full thickness, in which case it is abnormally thin for the area as a whole. Alternatively it may be but a lower post of the limestone with the remainder not exposed. One would expect any significant limestone development above this to be revealed in at least one section, however. So it does seem that if the full thickness is not seen, the exposed portion cannot be far short of the total. In Brokersgill Sike, a mass of loose shale is seen immediately above the limestone, but this is probably all in-filling material thrown into the beck to form a road across the stream to the previously mentioned lead level (p.49). However, a water conduit through this shale, level with the top of the exposed limestone, suggests that no limestone exists immediately above that exposed.

In Stony Gill, some silty shales are seen above the Four Fathom Limestone, but no contact is seen. 160 yards upstream, at least 10 feet of sandy black and buff shale outcrop, overlain by 7 feet of ganistroid sandstone (shaly in part), and then 3 feet of dark, muddy limestone representing the Iron Post Limestone. No beds crop out above this until the Great Limestone is reached. The Quarry Hazle is here seen to make its first significant appearance, while the Iron Post Limestone has once more reverted to a limestone.

No further exposures of these beds occur until we reach Hudeshope Beck, and the horizon boundaries are conjectural, being drawn in relative to the position of the overlying Great Limestone, where this is proven.

Hudes Hope. - Except for one poor limestone exposure high up on the right bank of Hudeshope Beck, north west of Cockland Nook (954264), the Four Fathom Limestone and succeeding beds are first seen near the mouth of Smaisgill Sike; in a quarry to the north (948268), in the stream bed, and in the left bank of Hudeshope Beck for a short distance. Up to 14 feet of grey, crystalline limestone, dipping east north east at 3^{0} are seen, resting on a 3 feet 6 inches fireclay. Between 4 feet and 5 feet from the base, a coral band, with rolled Clisiophyllids, exists, amounting to no more than 2 inches or 3 inches thick. This band was not detected in any of the previous exposures, but Miller and Turner (1931) record it in the Dent Line District, the Shap District, and from near Brough. They state that it occurs about 2 feet above the base of the limestone. H. Reading (1954) records it over the whole of the Stainmore Syncline, except for Greta River. It is usually situated 6 feet above the base of the limestone, has chert nodules associated with the band, and is normally 2 feet thick, but thins to the east down Lunedale. No chert nodules were seen in the Snaisgill exposure.

The Four Fathom Limestone is well jointed here, in two directions : north 25° west, and north 55° east. Above the limestone, 14 feet of black silty shale with scattered nodules and bands of clay ironstone occur. A gap ensues, followed by the exposure of coarse grained, flaggy, buff sandstone passing up into shaly sandstone and sandy shale, totalling approximately 6 feet, below the Great Limestone. No coal, is seen below the limestone. The beds here dip north east at 20° into a north west - south east branch of the High Dyke Vein, which has a small easterly downthrow. The vein itself is not seen, because of rock debris in the stream bed. No sign of the Iron Post Limestone or Quarry Hazle is seen.

On the right bank of Hudeshope Beck opposite Snaisgill Quarry 8 feet of the Four Fathom Limestone are exposed, dipping north east at 3°. Thence upstream, on both sides, the limestone can be traced until it crosses the beck below Skears Limekiln (949271). Up to 15 feet of light grey crinoidal limestone are exposed, and the coral band, still with rolled corals, no chert nodules, and up to 3 inches thick, situated 5 feet from the base, can be located both in the stream bed below Skears Limekiln and in the banks downstream from the mouth of Howgill. At the last mentioned locality, the limestone dips at 3° to the north east, increasing below the bridge near the limekiln to 16° to the north east, where the Aukside Vein crosses the beck in an east north easterly direction. The vein downthrows 2 or 3 feet to the north at this point. A dip of 10° to the south east in the Four Fathom Limestone in How Gill 40 yards from the mouth of the stream, marks the point where the Aukside Vein crosses the stream. The limestone, which is terminated at this point, is buff coloured and veined with calcite. In the left bank of Hudeshope Beck, opposite How Gill, a dip of 8° south south west in some shales and sandstone below the limestone, probably represents the continuation of the north west - south east High Dyke Vein.

The steep bank of Hudeshope Beck below Skears Quarry (948272) gives an almost continuous section from the top of the Four Fathom Limestone up to, and above, the Iron Post Limestone. The beds immediately above the limestone are obscured by loose shales for 3 or 4 feet, but above this, fine grained black carbonaceous shales with ironstone nodules, passing up into black sandy shales, and then buff sandy shale, totalling 38 - 40 feet are exposed, followed immediately by the Iron Post Limestone. Here, the 'limestone' is represented by 3 feet of calcareous sandstone and is overlain by 11 feet of sandy, black shale, grading up into 12 feet of shaly sandstone and sandy shale. A short distance above, the Great Limestone is quarried, but no contact with underlying beds is seen. The Quarry Hazle is completely absent here, but upstream, the shale sequence below the Iron Post Limestone is seen to get increasingly sandy from the top downwards so that in the left bank near Low Skears Mine (947276), sandy shales can be seen to grade laterally upstream into a buff sandstone with carbonaceous streaks (shaly in parts) totalling 10 feet opposite the mine. The nature of the Iron Post Limestone has also changed to the north. Opposite the mine it takes the following form :

	Ft.	Ins.
Limestone, fossiliferous at the base (upper post)	0	8
Crinoidal limestone (middle post).	1	6
Muddy limestone (lower post.)	1	0

It is overlain by some sandy black, limonite-stained shale.

The Low Skears Mine level was driven to work Hall's Vein, a roughly north west - south east vein which crosses the beck at this point, bringing the Great Limestone down 60 feet on the north. Below the Great Limestone at this point, 8 feet of medium grained, buff, ganistroid sandstone, with some thin black shale partings, represents the Tuft. Upstream, some sandstone is exposed below the Great Limestone, but drift and alluvium obscure most of the succession. On the right bank of the stretch of Hudeshope Beck so far described, thick drift conceals the solid geology down to How Gill.

Further valuable information is forthcoming from the shaft records in and around Hudes Hope. The important facts arising from these records (fig. 1 p. 14) concerns the sandstone developments. Thus in Skears Great Rise, a 20 feet thick Four Fathom Limestone is succeeded by 30 feet of shales and a 30 feet thick Quarry Hazle, while in Vein F the Quarry Hazle is reported as being only 10 feet thick resting on 40 feet of shale and with no mention of the Four Fathom Limestone occurring. The Vein F. section is 500 feet south of Skears Great Rise. A section from the Westmost Skears Mine in Vein D. (to the east of Vein F.) records a 12 feet Quarry Hazle. There is, therefore, a definite northerly or north-westerly thickening in the Quarry Hazle. Figures from a section given for the Lodgeside - Coldberry Mines show only 3 feet 6 inches for the sandstone, but this sandstone probably represents a sandy facies of the Iron Post Limestone (which is not recorded), with the Quarry Hazle absent. Where exactly this section was taken from is not clear.

The Tuft likewise is greatly thickened in Skears Great Rise, totalling 30 feet, with thicknesses of 7 feet and 6 feet in Vein F and Vein D, respectively, to the south and south east. The Coldberry - Lodgesike section shows 12 feet of sandstone at this horizon. It will be recalled that the Tuft is at least 20 thick thick to the north west in Blea Gill, but is represented by a mere 4 feet of ganistroid sandstone in Brokersgill Sike to the south west, and presumably if it thickened to any extent to the south east along Bell Edge, some sign of it would be seen. Thus we have a sandstone becoming attenuated on three sides, a ribbon development. Similar conditions arise when we examine the Quarry Hazle, and possibly the Nattrass Gill Hazle, the significance of which will be discussed later (p.356).

Country east of Hudes Hope. - Apart from two isolated exposures of medium grey, limonite stained, crinoidal limestone in small streams east of Middleton (950258 and 953256), which show that the strata have a fairly steep south easterly dip, bringing the Four Fathom Limestone down from near the 900 feet contour to the 800 feet contour, the beds in this part of the succession are not seen until a series of north - south tributary streams which join the Tees east of Bridge Sill. In this tract, the run of the beds is conjectured in relation to the more prominent overlying strata. Howgill Sike affords the best section. 60 yards upstream from the Tees confluence, the Four Fathom Limestone is exposed, dipping east south east at 4°, as a coarse grained, grey, limonite stained, crinoidal limestone, a thin section of which reveals it to be microfossiliferous, and containing siderite. It is in contact with a member of the

Cleveland Dyke system, but shows no obvious signs of alteration. Exposures above this are intermittent, but an outcrop 30 or 40 yards upstream of poorly fossiliferous, black, limonite stained, silty shales (965253) is important for the discovery of <u>Tylonantilus nodiferus</u> Armstrong (early mut.) (see pp. 62-3).

The Iron Post Limestone outcrops in the stream bed a further 100 yards upstream, and along both banks. It is 7 feet thick and consists of a limonite stained crinoidal limestone passing laterally and vertically into a calcareous, shaly sandstone. The underlying Quarry Hazle is a massive 6 feet buff sandstone. The 'limestone' is exposed in the stream to the west as an 8 feet sandstone, calcareous and shelly at the top, jointed in two directions, north 22° west, and north 57° east. To the east, in another north - south tributary stream, the Four Fathom Limestone, dipping east south east at 5° crops out a similar distance from the Tees, just above the 700 feet contour, and is again in contact with the Cleveland Dyke. 11 feet of massive, grey, crinoidal limestone are seen, but no succeeding beds are revealed. To the east, along the 700 feet contour, the limestone outcrops spasmodically for 300 yards, and can be linked with an outcrop in Intake Sike by means of a limestone exposure approximately 160 yards west of Intake Sike (971250). Near the mouth of the sike, and for 110 yards upstream, 10 feet of crinoidal limestone are revealed. The Cleveland Dyke, 27 feet wide, is seen in the stream nearby, and a certain amount of recrystallization of the limestone has taken place near the dyke. In all these exposures of the Four Fathom limestone no coral band has been seen.

30 yards upstream, a waterfall gives a good section of the

succeeding beds :

	Ft.	Ins.
Ganistroid sandstone.	3	6
Sandy grey shale.	2	6
Fine grained buff sandstone.	7	6
Sandy shales and sandstones.	4	6
Coal smut.	0	3
Sandy black shale.	8	4
Medium grained grey micaceous sandstone, calcareous in parts.	10	0
Black micaceous shale.	6	0
Four Fathom Limestone.		

This coal has not been met with elsewhere in the area. It is difficult to select any one sandstone and call it the Quarry Hazle, but the important thing is the relatively strong development of sandstone here, below the Iron Post Limestone, which is probably represented in a composite exposure dipping north north east at 3^{o}, 40 yards upstream :

	Ft.	Ins.
Grey, limonite stained, coarse grit, calcareous at top.	3	6
Grey ganister.	2	0
Sandy grey shale, grading down into -	0	8
Calcareous grey sandstone, micaceous and shaly in parts.	3	0
Sandy buff shale.		

60 to 70 yards further upstream, a 6 feet quartzitic sandstone possibly represents the Tuft, or part of it, dipping due north at 18^{o}. The relatively steep dip indicates the presence of a north north west fault throwing the Great Limestone down to the same level as the Four Fathom Limestone (700 feet O.D.), 200 yards to the east (975247), (see p.121).

At Eggleston Bridge 20 feet of grey crinoidal limestone represent the Four Fathom Limestone in a faulted inlier. A coral band, 4 inches to 6 inches thick, containing rolled clisiophyllids, and no chert nodules, is located 5 feet from the base of the limestone.

<u>Lunedale.</u> - North of West Pasture Road, largely overgrown quarries with some exposures of coarse, crinoidal grey limestone, and a feature, enable one to map the Four Fathom Limestone with confidence for a distance of over 650 yards, below the Great Limestone. No sign of the Iron Post Limestone, or Quarry Hazle is seen, but at the mouth of Easter Beck, on the shores of Grassholm Reservoir, some medium grained buff sandstone is seen below the Great Limestone. The Tuft, is finally seen in an old quarry south of West Pasture Road (958228), where 2 feet of medium to coarse grained ganistroid sandstone underlies the Great Limestone, dipping south into the Stainmore Syncline.

PALAEONTOLOGY.

It should be stated at the outset that the palaeontological work is not complete, in that additional work could be carried out on the material collected. A search has been made for material which would be of use in establishing the true age relationships of the strata concerned, and in effecting a correlation with outside areas. Apart from this, the author could not devote the time neccessary for a complete and thorough examination of the faunal collection. The more important and interesting aspects of the collection have been recognised and their significance briefly discussed.

"? Cyathaxonia sp.", listed in the fauna of the Alternating Beds below the Single Post Limestone, refers to two moulds of coral calyces (one slightly crushed) (No. 328) in famped, sandy limestone. The better preserved mould compares favourable with an illustration by Demanet (1938 pl. 1) of an internal mould of the calyx of Cyathaxonia cf. rushiana Vaughan. Numerous sharp, narrow depressions (representing the septa) are seen, but it is difficult to recognise minor septa which is necessary in differentiating between Cyathaxonia and Lophophyllum. There is a central depression corresponding to the position of the raised axial column. The size of the mould (i.e. the calyx) is slightly larger than that illustrated by Demanet. Garwood (1912, 1924) recorded C. rushiana in the shales immediately above the Scar Limestone in Rundale Beck, Westmorland and a short distance below the Orionastraea Band (base of D3) in Stockdale Beck, Yorkshire. Turner (1927) records Cyathaxonia from the Scar Limestone in Maize Beck, Westmorland. C. rushiana is listed by D. Hill (1938

p. 6.) as occurring in C2, D1, and her lower Coral Zone 2 (from the base of D2 to the base of the Simonstone Limestone). She does not record it in her Upper Zone 2 (up to the top of the Single Post Limestone) or in Zone 3 (up to the top of the Great Limestone). Cyathaxonia cornu is recorded by Hill in Z2, γ, C1, C2, lower Coral Zone 2, and Zone 3, but not in Upper Zone 2.

Lithostrotion junceum (Fleming) occurs in the Cockle Shell Limestone on Crossthwaite Common (No.268). Garwood (1924) found it to be characteristic of the Orionastraea Band of Ingleborough and the Settle District in general. On Ingleborough it was noticeable for the small size of the corallites, which were less than 2 mm. in diameter. This is also true of the specimens from Crossthwaite Common. The Orionastraea Band is represented by the Tynebottom - Single Post Limestone horizons within the Alston Block (Turner 1927). Turner has recorded L. junceum from the Lower Little Limestone in Scordale, the Jew Limestone, the Tynebottom Limestone, the Single Post Limestone, the Cockle Shell Limestone in Siss Gill, Westmorland, and the Scar Limestone (being the only abundant form in this limestone in the Westmorland Pennines). Dorothy Hill reports its presence in Upper Zone 2 and Zone 3. It is also recorded in the Cockle Shell and Five Yard Limestones of the Roddymoor borehole (Lee 1924, p. 147). In the present area it has not been found above the Cockle Shell Limestone, and G.A.L. Johnson states that it does not occur above the Five Yard Limestone in south western Northumberland (1953, p. 206) and considers this to be its probable upper limit.

The Cockle Shell Limestone is notable for its abundance of Productus (Gigantoproductus) giganteus Martin, which gives the limestone its name. These forms also occur in the Five Yard

Limestone, but less abundantly. Apart from occurrances in the Great Limestone of Weardale, and in this area, it is not recorded above the Five Yard Limestone.

The macrofauna of the Four Fathom Limestone is almost restricted to a fossil band of 6 inches thick, or so, situated 5 feet from the base of the limestone in this area. Rolled clisiophyllid corals form the bulk of the fauna consisting of Dibunophyllum bipartitum varieties with konincki forms in the ascendancy, followed by the bipartitum forms. Hill (1938, p. 18) states that konincki is the dominant form in beds from the Single Post Limestone to the base of the Little Limestone. Aulophyllum fungites Fleming mut. pachyendothecum Thomson, is also well represented, and some of the specimens have dilated septa on either side of the cardinal fossula. Hill reports this coral from D1 and Zones 3 and 4. Various brachiopods accompany the corals, with P.(Gigantoproductus)latissimus J. Sowerby as the most common form.

The Scar and Three Yard Limestones, which have very restricted macrofaunas (mainly from shale partings) are succeeded by a few feet of very fossiliferous shales with a dominantly brachiopod - crinoid - bryozoan fauna. Similar but poorer marine shales occur above the Single Post, Five Yard, and Four Fathom Limestones. The latter is particularly important for the discovery of Tylonautilus nodiferus Armstrong early mut. Stubblefield, approximately 15 to 20 feet above the limestone in Howgill Sike (see p. 57). A speciman referred to Pleuronautilus nodosocarinatus was found in the Little Limestone of Swarth Fell (Rhodes in Wheelton Hind 1902, p. 295). Stubblefield re-examined this and considered it to be T. nodiferus early mut.

This form has been identified from several horizons, from the uppermost part of P2 Visean to E1c Namurian, the normal horizon for its occurrence being E1c according to Trotter (1952 p. 86). It has been recorded from Ireland at a horizon regarded as high P2 or low E1 by Stubblefield (Hartley 1945, p. 259). It was located in the shales above the Four Fathom Limestone of Elf Hills, Cambo, Northumberland, and of Bardon Mill, Northumberland (Johnson, personal communication in litt., Nov. 1956). Rowell (1953, p. 25) records it from shales above the Great Limestone. Various lines of evidence point to the base of the Great Limestone as the base of the E1 subzone (see pp. 335-337) so that the present occurrence of T. nodiferus early mut. is almost certainly of high P2 age.

All the persistent limestones are microfossiliferous, and perhaps the most important occurrences in the Middle Limestone Group are Howchinia bradyana Howchin in the Scar Limestone (No. 36a) and the Single Post Limestone (No. 23) (the latter not definite), and "Algae α" Johnson in the Four Fathom Limestone (Nos. 4 and 318). H. bradyana, according to Johnson (1953. p. 218) makes its last appearance in the Three Yard Limestone of Northumberland, while Davis (1951, p. 248) states that it occurs from P2 to well into the D zone.

Johnson (1953, p. 45) maintains that "Algae α" is abundant in, and almost restricted to the top of the "Upper Main Post" of the Great Limestone. He found it at this horizon over a wide area extending from Morpeth in the north, to Barnard Castle in the south. It has also been found in the Four Fathom Limestone at one locality, and a single fragment tentatively referred to this organism occurs in a section of the Five Yard Limestone. Short (1954, p. 145) locates "Algae α" in the Five Yard Limestone of the Pennine Escarpment between Croglinwater and Ardale, but records a maximum in the Great Limestone. It occurs in Four Fathom specimens from Hudes Hope (No. 4) and Lunedale (No.318) in the present area.

Archaedisous karreri Brady was recorded by Johnson (1953, p. 218) as making its last appearance in the Three Yard Limestone of Northumberland. Short (1954, p. 122) however, divided into three varieties, var α, var β, and A.karreri ss. The latter was recorded as high as the Little Oakwood Limestone, while var α was abundant from the upper part of his Upper blue-grey group of the Melmerby Scar LImestone to the Five Yard Limestone, and absent or rare above. Var β was abundant above and below the var a limits. Archaedisous karreri ss., (Nos. 19, 318) and less commonly var β (No. 16) has been located in the Four Fathom Limestone and the Iron Post Limestone in the Middle Limestone Group, and also in the Upper Limestone Group (see p. 225) in the present area.

A significant absentee is Saccamina canteri Brady from the Four Fathom Limestone, which sometimes contains it in sufficient abundance to merit the name "Spotted Post".

FAUNA OF THE MIDDLE LIMESTONE GROUP.

The Alternating Beds (below the Single Post Limestone).

Fenestella spp.
Penniretopora sp.
Rhabdomeson sp.
? Cyathaxonia sp.
Martinia sp.
Productus (Buxtonia) scabriculus Martin.
--------- (Echinoconchus) cf. elegans McCoy.
--------- (Productus) sp.
Spirifer sp. s.s.
Edmondia accipiens J. de C. Sowerby.
Stroboceras sp.

The Single Post Limestone.

Archaediscus karreri Brady s.s.
Bradyana cf. grandis Paeckelmann.
--------- cf. nautiliformis Moller.
Climacammina antiqua Brady.
Cribrostomum bradyi Moller.
Endothyra crassa Brady.
--------- bowmani Moller.
--------- ornata Brady.
cf. Howchinia bradyana Howchin.
Valvulina (Tetrataxis) decurrens Brady.

Shales below the Cockle Shell Limestone.

Fenestella sp.
Productid spines.
Productus (Eomarginifera) sp.
Spirifer bisulcatus group J. de C. Sowerby.

The Cockle Shell Limestone.

Ammodiscus cf. concavus Spandel.
Bradyana cf. grandis Paeckelmann.
Cribrostomum bradyi Moller.
Endothyra ornata Brady.
Valvulina (Tetrataxis) decurrens Brady.
Lithostrotion junceum (Fleming).
Productus (Gigantoproductus) giganteus group Martin.

The Scar Limestone.

Archaediscus karreri Brady s.s.
Cribrostomum bradyi Moller.
Cribrogenerina.
Endothyra cf. ammonoides Brady.
---------- cf. bowmani Phillips.
---------- crassa Brady.
---------- ornata Brady.
Howchinia bradyana Howchin.
Valvulina (Tetrataxis) decurrens Brady.

Valvulina (Tetrataxis) palaeotrochus Ehrenburg.
Athyrids.
Productus (Echinoconchus) punctatus Martin.
--------- sp.
Spirifer sp. s.s.
Nucula oblonga McCoy.
Pterinopecten sp.
Stroboceras sp.

Shales above the Scar Limestone.

Fenestella sp.
Athyris sp.
Brachythyris sp.
Chonetes hardrensis group Phillips.
-------- (Chonetes) cf. laguessianus de Koninck.
Cleiothyridina cf. roysii Leveille.
Lingula cf. elongata Demanet.
Productus sp.
--------- (Productus) cf. concinnus J. Sowerby.
--------- (---------) productus group Martin.
Rhynchonella (Camarotoechia) cf. pleurodon Phillips.
Smooth Spirifer.
Amuseum cf. tenue de Koninck.
Aviculopecten cf. carbonaria
Edmondia arcuata Phillips.
-------- goldfussi de Koninck.
-------- sp.
Eumicrotis hemisphericus (Phillips).
Nucula laevirostris Portlock.
------ cf. oblonga McCoy.
Nuculana attenuata Fleming Gisement.
-------- cf. laevistriata Meek and Worthing.
Nuculopsis gibbosa (Fleming).
Palaeoneilo fecunda Hall.
Protoschizodus cf impressus de Koninck.
Syncyclonema carboniferum Hind.
Bucaniopsis moravicus Klebelsburg.
Euphemites urei (Fleming).
Euphemus jacksoni Weir.
-------- sp.
Loxonema sp.
Ptychomphalus sp.

The Low Brig Hazle.
Mollusc trail - Eione (Tate).
Annelid tracks.

The Five Yard Limestone.

Archaediscus karreri Brady s.s.
Endothyra crassa Brady.
--------- ornata Brady.
Productus (Gigantoproductus) giganteus group Martin.

Shales above the Five Yard Limestone.

Rhipidomella cf. michelini Leveille.

Schizophoria cf. resupinata Martin.
Spirifer sp. s.s.
Epistroboceras sp.
Stroboceras sulcatum (J. de C. Sowerby).
Three indeterminate orthoconic nautiloids.

The Three Yard Limestone.

Calcisphaera sp.
Archaediscus karreri Brady s.s.
Cribrogenerina.
Cribrostomum bradyi Moller.
Valvulina (Tetrataxis) palaeotrochus Ehrenberg.
Textularia sp.
Fenestella sp.
Ptilopora sp.
Spirorbis.
Edmondia sp.
Nuculid.
Cycloceras sp.
Zygopleura sp.

Shales above the Three Yard Limestone.

Plant remains.
Archaeocidaris echinocrinus
Crinoid infra-basals.
Crinoid ossicles up to 13 mm. diameter.
Fenestella sp.
Penniretopora sp.
Chonetes hardrensis group Phillips.
-------- sp.
Productus (Buxtonia) sp.
--------- (Gigantoproductus) latissimus group J. Sowerby.
--------- (Linoproductus) sp.
---------(? Overtonia) sp.
--------- (Pustula) sp.
--------- spp.
Spirifer bisulcatus group J. de C. Sowerby.
Aviculopecten cf. clathratus McCoy.
Edmondia sp.
? Leioptera sp.
Nucula cf. oblonga McCoy.
------ sp.
Posidoniella cf. minor Brown.
Pseudamuseum cf. concentrico-lineatum Hind.
Sanguinolites cf. ovalis Hind.
Dentalium.
Euphemus sp.

The Four Fathom Limestone.

Calcisphaera sp.
? Apterrinella sp.
Archaediscus karreri Brady s.s.
------------------------- var β (Short).
Climacammina antiqua Brady.

Cribrogenerina.
Cribrostomum bradyi Moller.
Endothyra bowmani Phillips.
--------- crassa Brady.
--------- ornata Brady.
Valvulina (Tetrataxis) decurrens, Brady.
--------------------- palaeotrochus Ehrenberg.
"Algae α" Johnson.
Aulophyllum fungites Fleming mut. pachyendothecum Thomson.
Dibunophyllum bipartitum bipartitum McCoy.
------------------------ craigianum Thomson.
------------------------ konincki Edwards and Haime.
Diphyphyllum lateseptatum McCoy.
Koninckophyllum magnificum Thomson and Nicholson.
Dielasma cf. hastata (Davies).
-------- cf. sacculus (Martin).
Orthotetid indet.
Productus (Gigantoproductus) latissimus group J. Sowerby.
---------(Eomarginifera)longispinus J. Sowerby.
--------- (Echinoconchus) elegans McCoy.
--------- sp.
Spirifer bisulcatus group J. de C. Sowerby.

Shales above the Four Fathom Limestone.

Productus (Overtonia) sp.
Schizophoria resupinata (Martin).
------------ cf. swallovi (Hall).
Spirifer bisulcatus group J. de C. Sowerby.
Nucula cf. luciniformis Phillips.
------ oblonga McCoy.
Cycloceras sp.
Orthoconic nautiloid.
Tylonautilus nodiferus Armstrong early mut. Stubblefield.

The Iron Post Limestone.

Ammodiscus sp.
Archaediscus karreri Brady var β (Short).
Endothyra bowmani Phillips.
--------- ornata Brady.
Crinoid ossicles up to 2 mm. diameter.
Productid spines.
Productus sp.
Spirifer bisulcatus group J. de C. Sowerby.

PETROGRAPHIC NOTES.

The numbers quoted in brackets are specimen numbers; those underlined denote sectioned rocks.

The Tynebottom Limestone (No.319) - a fine to medium grained limestone, grey in colour but stained with limonite in places, and having a siliceous appearance. It is recrystallized to a certain extent. The limonite staining is the result of the alteration of a concentration of a carbonate with ($N_e > 1.54$) probably siderite, which forms up to 25% of the section. No organic remains were seen, probably a result of the recrystallization.

The Single Post Limestone. (Nos.23, 273b, 275, 325b and c). This is normally (in this area) a dark grey, fine grained, rather muddy limestone, containing some shell debris. It is microfossiliferous, containing various foraminifera set in a matrix of finely crystalline limestone with numerous streaks and pockets of black carbonaceous material. It is thermally metamorphosed by the underlying Whin Sill on Crossthwaite Common (No.273b) and in the Tees above Scoberry Bridge (No.275), being a light grey saccharoidal limestone, veined with siderite (probably by later mineralization processes). The siderite ($N_e > 1.54$) is largely stained with iron oxide. In Rowton Beck, Crossthaite Common, the metamorphosed limestone (No.273b) contains numerous flakes of chlorite (penninite) intimately associated with ore in pockets. All organic remains have been obliterated in the process of complete recrystallization.

The Cockle Shell Limestone. (Nos.268, 325d) - a dark grey, fine grained, frequently muddy limestone containing numerous characteristic gigantoid productids (<u>Productus (Gigantoproductus) giganteus group Martin).</u> It is generally microfossiliferous, with various foraminifera set in a background of fine grained calcite, clouded with liberal amounts of carbonaceous material.

<u>The Scar Limestone.</u> (Nos. <u>32</u>, <u>36a</u>, <u>42</u>, <u>48</u>, <u>93</u>, <u>94c</u>, 95, 272, 273). The Scar Limestone is blue-grey, or grey in colour, fine grained, crinoidal in places, and often sandy at the base. Fragments of clear calcite are set in a groundmass of fine grained calcite containing much carbonaceous material. It is microfossiliferous. In the basal sandy part of the limestone (No.94c) up to 25% or 30% of the rock consists of small (.05 - .1 mm. diameter) clear, angular quartz grains. Cubes of iron pyrites occur locally (Nos. 36a, 272).

<u>The Low Brig Hazle.</u> (Nos. <u>28</u>, <u>41</u>, <u>45</u>, <u>46a</u>, 96) - a fine to medium grained (.05 - .25 mm. diameter) generally compact and flaggy, micaceous sandstone. It is usually grey or buff in colour, but sometimes a greenish brown (46a), due in this case to a fairly abundant brownish interstitial clay minerals. Constituents are dominantly quartz grains, with less than 1% of plagioclase felspar. Muscovite mica is fairly plentiful, and at Breckholm Pool (No.28) is arranged in closely spaced layers, giving the rock a banded appearance. Some interstitial calcite is also present in the latter locality, while in Newbiggin Beck (No.41) calcite forms an abundant cement. At Unthank Bank in the River Tees (No.45) and in Newbiggin Beck, the sandstone is pyritous. Accessories include some rounded zircons and tourmaline.

<u>The Five Yard Limestone.</u> (No.<u>24</u>). This limestone is grey, fine grained, crinoidal in places, and contains some giganteid

productids. It consists of fragments of clear organic calcite set in a turbid groundmass of calcite and siderite ($N_e > 1.54$). It is microfossiliferous.

The High Brig Hazle. (Nos. 41a, 18, 55, 99, 278, 279) - compact, fine to medium grained (.05 - .25 mm. diameter) buff or cream coloured sandstone frequently containing specks of limonite. It is micaceous in some places, with muscovite and some hydrobiotite (Nos. 41a, 55). The quartz grains, which constitute 95% of the rock are angular and sub angular and frequently show undulose extinction and slightly biaxial figures with a 2E of up to 5°. Secondary silica mantles some of the grains (No.55) but is not present in nearly sufficient quantity to attain the status of a cement. Interstitial pockets of clay minerals occur (41a), but not in abundance. Felspar is apparently rare, but some clouded albite grains occur in the Newbiggin Beck exposure (No.55). Accessories include zircon, rutile, and tourmaline. Limonite patches occur in most specimens.

The Three Yard Limestone. (Nos. 1, 2, 54, 97, 241). This is a normal Middle Limestone Group limestone, being fine grained, grey, and crinoidal in places. It consists of organic debris (mainly crinoidal) set in fine grained calcite, and also contains microfossils. At one point in Hudeshope Beck (No.241) it contains a liberal amount of stained siderite. ($N_e > 1.54$).

The Nattrass Gill Hazle. (No.4). Where developed it is a fine to medium grained (.02 - .1 mm. diameter) thinly bedded, buff-grey, micaceous sandstone of a compact nature. The angular quartz grains are cemented with calcite and stained siderite ($N_e > 1.54$) at the mouth of How Gill. Muscovite and biotite are fairly abundant, and patches of limonite frequently occur. A few grains of zircon are present.

<u>The Four Fathom Limestone.</u> (Nos. <u>4a</u>, 12, <u>13a</u>, <u>14</u>, <u>19</u>, 261, <u>318</u>, 333) - A fine to coarse grained grey limestone, frequently muddy at the base and the top, and generally crinoidal. It is fossiliferous, containing rolled corals concentrated in a thin (up to 6 inches) band situated approximately 5 feet from the base. It largely consists of fragmentary organic calcite set in a groundmass of fine to medium grained calcite (which is muddy in places) with a varying amount of stained siderite ($N_e > 1.54$). No. 14 is largely made up of stained siderite rhombs. The limestone is microfossiliferous. No chert was seen in the limestone.

<u>The Iron Post Limestone.</u> (Nos. <u>16</u>, <u>239</u>, 242, <u>270</u>, <u>334</u>). This is a highly variable horizon, ranging from a fine grained, grey, fossiliferous limestone, to a sandstone which may or may not be calcareous. The limestone may be muddy dark grey and very tough (No.16) consisting of a fine grained aggregate of calcite with bitumenous and black carbonaceous material, and patches of clearer calcite and calcite organic fragments. It may be microfossiliferous (No.16), or devoid of microfossils (No.270). Stained siderite ($N_e > 1.54$) is present in some places (No.270). The sandstone developments may be calcareous (No.239), or non calcareous (No.334). The latter consists of at least 50% of small (.05 - .2 mm.) angular quartz grains, some of which show undulose extinction, set in a liberal (> 40%) interstitial material made up of clay minerals and carbonaceous material in roughly equal amounts. Muscovite is present in very small amounts.

The Whin Sill, referred to in connection with the Single Post Limestone, is a quartz dolerite intrusion (see pp. 368-372) which, in the area surveyed, maintains a relatively constant stratigraphical horizon, within the Alternating Beds, below the Single Post Limestone. The horizon is not absolutely constant however, 5 feet 6 inches of shale separating the two horizons in Lunedale, and 18 feet of shale and sandstone at Scoberry Bridge. Its thickness varies from 243 feet and 221 feet 6 inches in the Ettersgill borings (Dunham 1948, p. 52), to at least 140 feet in the quarries on Crossthwaite Common, thinning drastically to the south east where in the Lune River it totals only 18 feet.

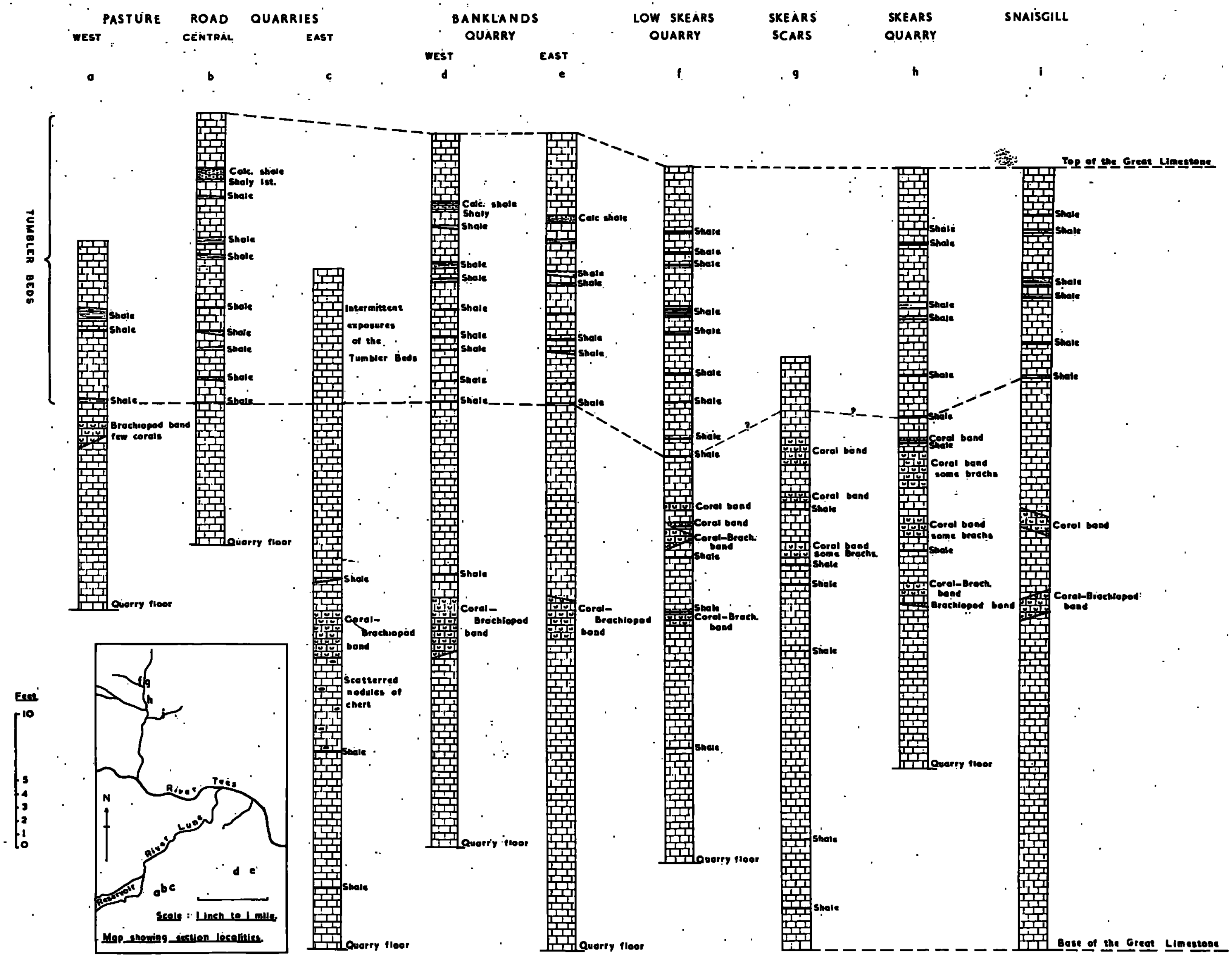


Fig. 2. COMPARATIVE SECTIONS OF THE GREAT LIMESTONE

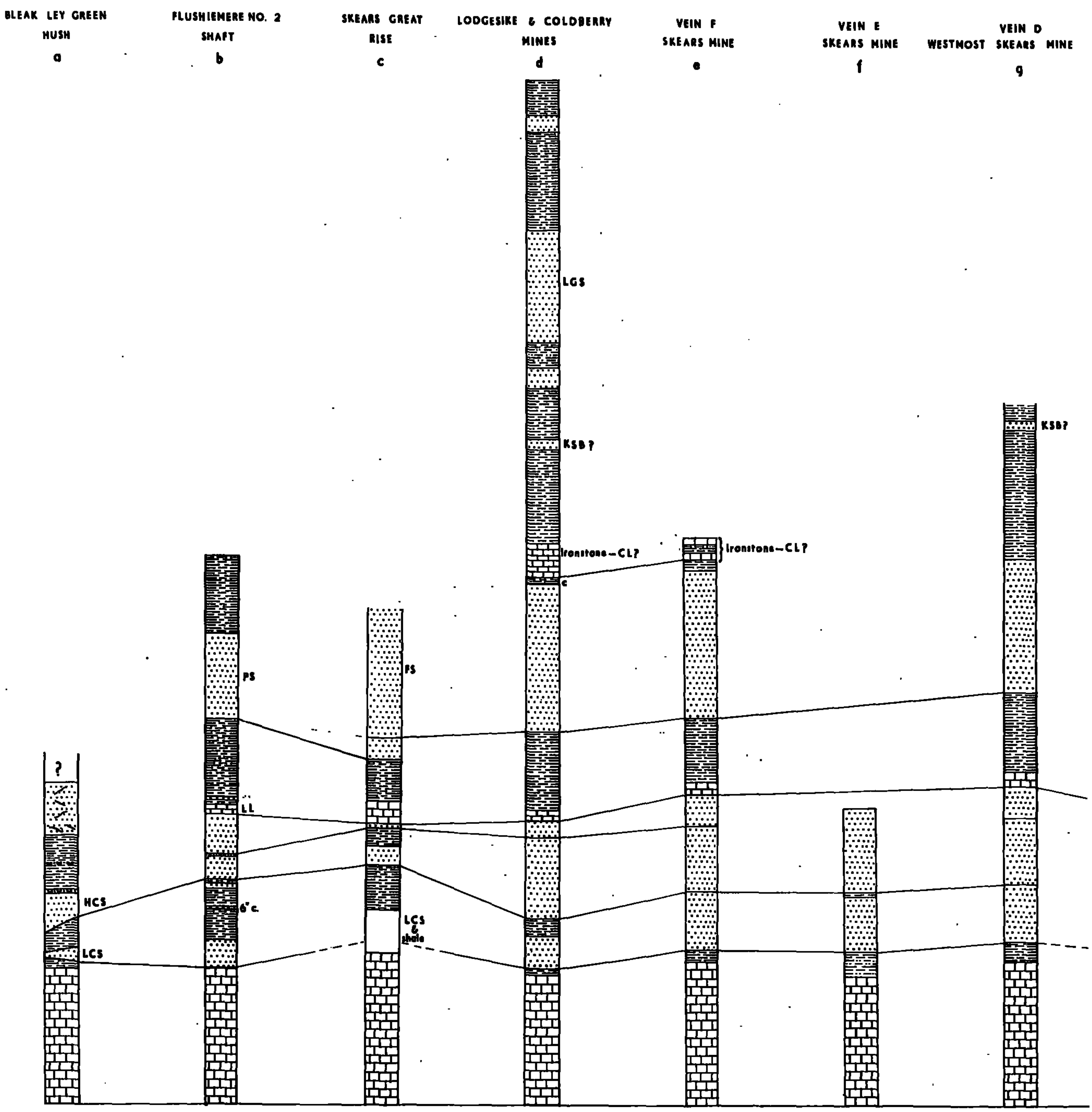


Fig. 3a. COMPARATIVE SECTIONS of the UPPER LIMESTONE GROUP

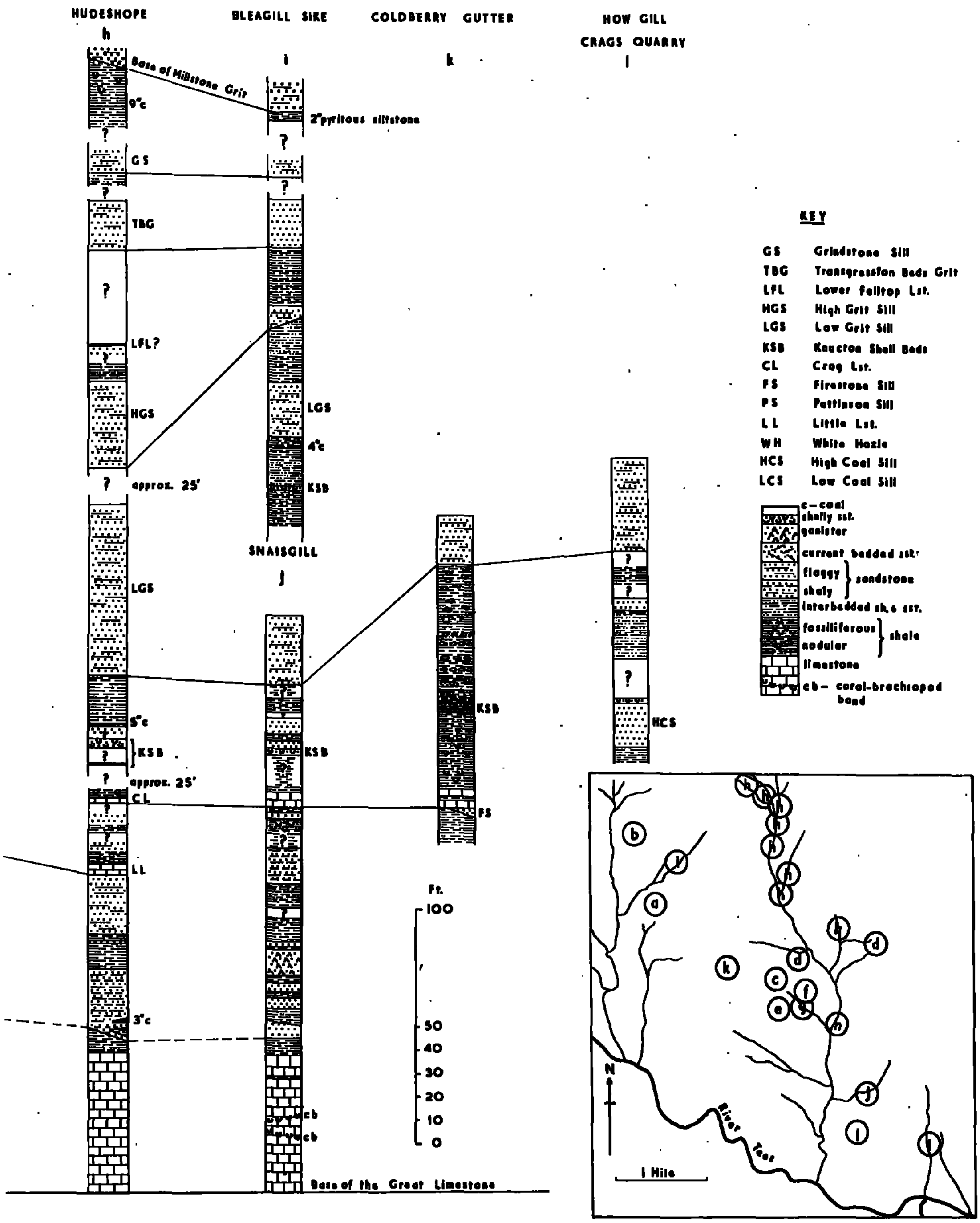


Fig. 3b. COMPARATIVE SECTIONS of the UPPER LIMESTONE GROUP

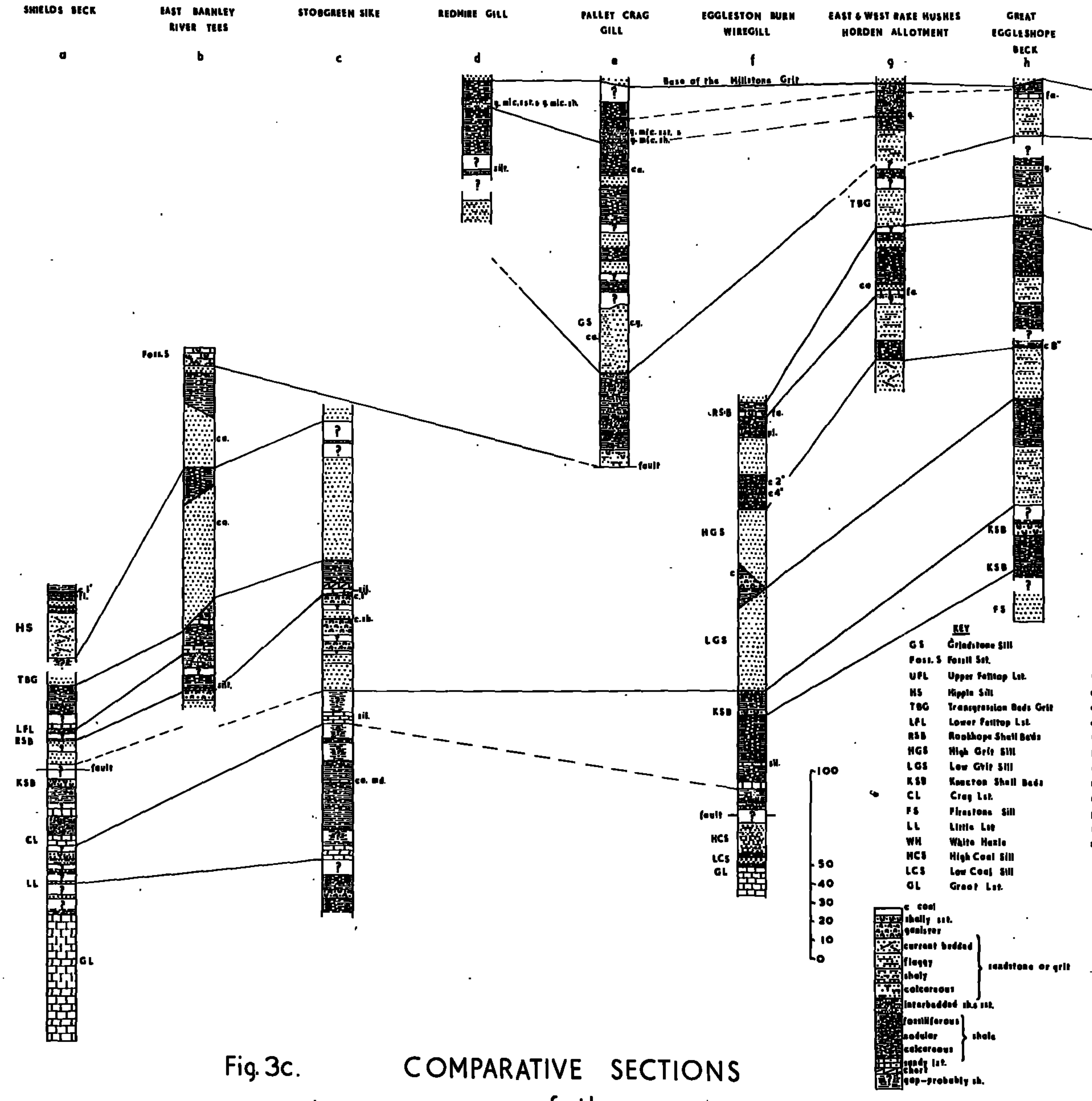


Fig. 3c. COMPARATIVE SECTIONS of the UPPER LIMESTONE GROUP

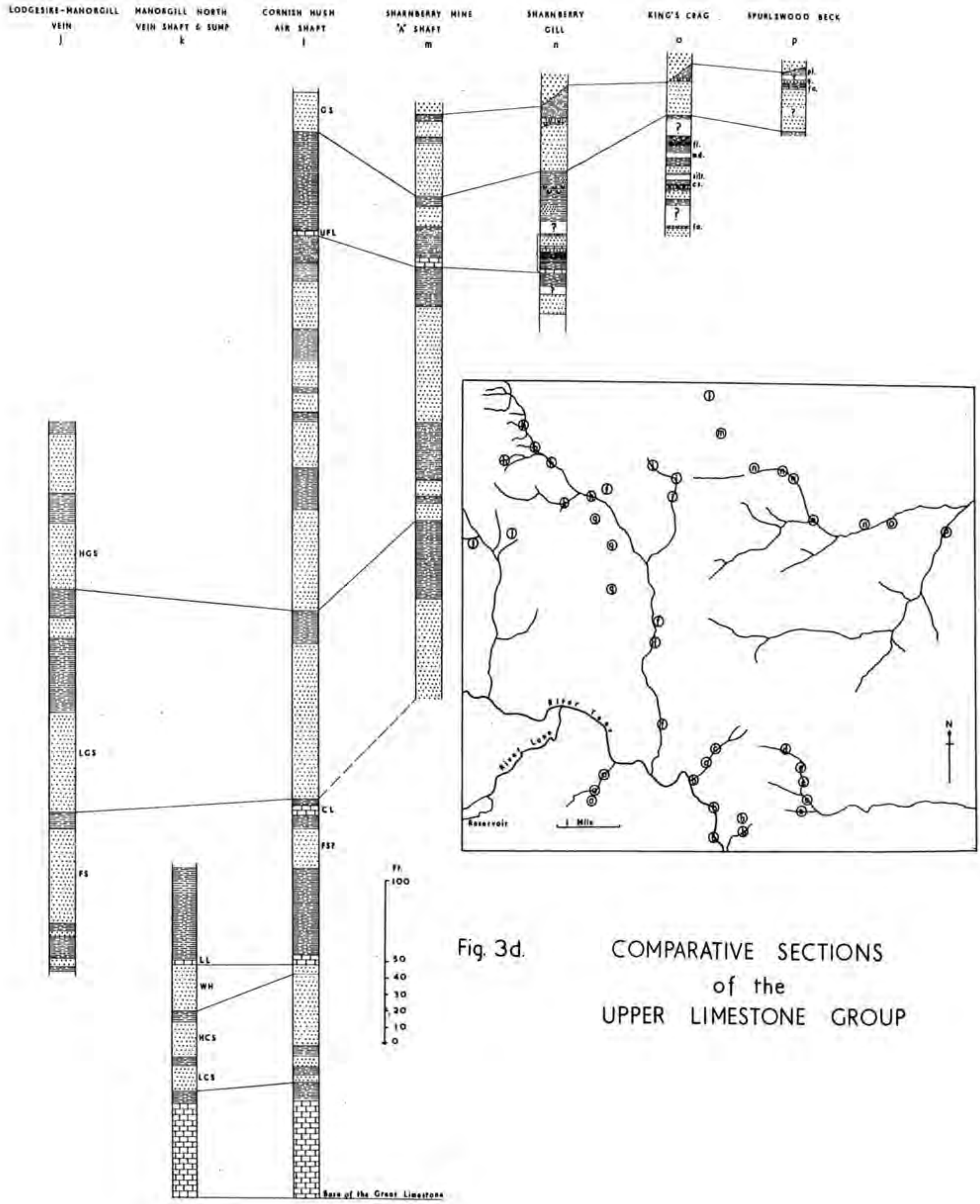


Fig. 3d. COMPARATIVE SECTIONS of the UPPER LIMESTONE GROUP

CHAPTER 3.

THE UPPER LIMESTONE GROUP.

GENERAL STRATIGRAPHY

The Upper Limestone Group consists of the beds from the base of the Great Limestone up to the base of the local "Millstone Grit," (see figs. 3 p. 74). The group is dealt with along the same lines as the Middle Limestone Group, with the succession being divided into five subgroups:

a) Beds from the base of the Great Limestone to the top of the Little Limestone.

b) Beds from the top of the Little Limestone to the base of the Low Grit Sill.

c) The Grit Sills and beds to the base of the Transgression Beds Grit; the Rogerley Transgression.

d) The Transgression Beds Grit and beds to the base of the Grindstone Sill; the Coalcleugh Transgression.

e) The Grindstone Sill and beds to the base of the First Millstone Grit.

As in the previous chapter, each subgroup is then described under locality headings.

The Upper Limestone Group is fully exposed in the western part of the area surveyed; in the Newbiggin - Hudes Hope area, in the Eggleston Burn - Great Eggles Hope and Little Eggles Hope area (except for the major part of the Great Limestone), and in Lunedale. To the east, the regional dip carries the lower members of the group below the surface.

The base of the group is taken at the base of the Great Limestone, following the practice adopted in this area, and the Northern Pennine Orefield as a whole, by K.C. Dunham (1948, p.25).

The succeeding beds retain the rhythmic sequence so characteristic of the Middle Limestone Group, but in a less marked degree, with the marine horizons becoming less prominent as we rise in the succession. Limestones are poorly developed, being thinner and less pure lithologically than their Middle Limestone Group counterparts. Indeed, on purely lithological grounds, the Great Limestone would seem to be better placed in the latter group. The arenaceous members of the sequence become generally coarser grained and assume a greater quantitative importance, with marked ribbon (or"washout") development at various horizons. Coals are also more numerous but generally are not of workable thickness.

Seven marine horizons have been mapped, four limestones, and three consisting largely of fossiliferous marine sandstone. Other marine horizons occur, but they have not been mapped as distinct units because of their isolated and infrequent occurrence. Lateral variation in the shale-sandstone members often renders correlation difficult, but the several marine horizons, although not impressive in themselves, have formed a reliable and rigid framework for the classification of associated strata, when they are exposed.

The primary surveyors mapped four thin limestones and two sandstones, the Firestone and Grindstone Sills (Dunham, 1948, p. 26), but the present survey shows that the former title was frequently misapplied to other, similar grits or sandstones, and that the Firestone Sill is in fact rather restricted within the area. Of the arenaceous horizons, five have been mapped, the Low and High Grit Sills, the Tranggression Beds Grit, the Hipple Sill, and the Grindstone Sill.

The Great Limestone is the thickest limestone in that part of the Carboniferous succession occurring within the area. It varies between 55 feet and 70 feet, the greatest exposed thickness being 68 feet in Bale's Hush, Flushiemere. Shale partings are developed in the upper part of the limestone, the interbedded shales and limestone being collectively referred to as the Tumbler Beds. These beds vary considerably in thickness, 9 feet being recorded in Snaisgill Sike, and 30 feet in Parkin Hush, Hudes Hope. Generally the thickness is between 15 feet and 20 feet. The shale partings vary in thickness from less than 1 inch to 2 feet. Shale partings also occur in the lower part of the limestone, but their frequency and distribution are inconsistent. Dunham (1948, p.27), speaking of the Northern Pennine Orefield in general, states that the limestone below the Tumbler Beds can be divided into 3 "flats", the High, Middle, and Low Flats, relative to partings situated 33 feet to 35 feet, and 15 feet above the base. These partings have favoured replacement in the process of mineralization. No such general subdivision can be effected in the present area.

Fossil bands containing rolled corals and brachiopods occur within the limestone, but their positions and frequency again are variable. Generally speaking they occur in the middle of the limestone, but in Bale's Hush, the limestone contains such bands practically throughout its entire thickness below the Tumbler Beds. Dibunophyllum bipartitum varieties, bipartitum, craigianum, and komincki, dominate the coral-brachiopod fauna, with konincki, the most common, as in the Four Fathom Limestone. One difference noted between the dibunophyllids of both these limestones is that the konincki varieties tend to develop dilated septa around the cardinal fossula. Aulophyllum fungites Fleming mut. pachyendothecum also has septal dilation but in a more marked degree than the Four Fathom specimens. This dilation phenomena was noted by G.A.L. Johnson in Weardale and Northumberland, but the dilation occurred in the Four Fathom Limestone corals, so that the difference must merely be due to environmental conditions. Lonsdaleia floriformis laticlavia Smith, occurs, and is restricted to the Great, or Main, Limestone in Northern England. The brachiopod fauna is varied, with Gigantoproductus latissimus (J. Sowerby) as the most common form The occurrence of Gigantoproductus group Martin spp. is of some interest. It has been recorded in the Great Limestone of Weardale, but does not usually occur above the Five Yard Limestone. It has not been recorded above the Great Limestone to the author's knowledge.

The most important member of the microfauna is "Algae α" Johnson, which G.A.L. Johnson (1953, p. 45) regards as being almost restricted to the top of the 'Upper Main Post' of the Great Limestone (see p. 63). Its abundant presence in a faulted limestone outlier at Lonton Limekiln (960244)was instrumental in establishing the identity of this limestone (No. 26) as the Great Limestone. It occurs, however, in the lower 15 - 20 feet of the limestone (see p.128) and has also been found in the Four Fathom Limestone in this area. Girvanella tubules were also located in this limestone.

Discreet bodies of chert are very rare in the Great Limestone but have been found in the main body of the limestone in the eastern quarry of the West Pasture Road Quarries in Lunedale, and in the shale partings of the Tumbler Beds in Bale's Hush, Flushiemere. The limestone itself is very similar to those of the Middle Limestone Group, being fine grained, grey or blue-grey, more or less crinoidal, and microfossiliferous. Except where drift covered, it tends to form prominent limestone scar features, as on Bell Edge in the Newbiggin area, and Newberry Scar in Hudes Hope.

A highly variable group of sandstones and shales, the Coal Sills, succeed the Great Limestone. Greatest interest within this group lies with the arenaceous beds. But before discussing the group, it is necessary to define the term "grit" as used herein. "Grit" is a term that has implied different things when used by different people. Westgarth Forster (1821, p. 96) used the term "Millstone Grit" to designate a bed which had a coarser grain than freestone, and the primary geological surveyors used "grit" to describe a similar rock. Gilligan (1919) used it for coarser sediments but gave no precise definition of grit or sandstone. He distinguished three grades of grit however, with the largest pebbles greater than ½ inch, less than ½ inch, and less than ¼ inch diameter respectively. Sandstones were rocks with pebbles less than ⅛ inch in diameter, though the average grain size must of course have been very much smaller. Modern petrologists employ the term "grit" for a sandstone with angular grains. H.G. Reading (1954, p. 14) employed the term "grit" for arenaceous beds with a grain size of greater than .25 mm., while beds with a grain size of .05 mm. to .25 mm. were called sandstones. Initially an attempt was made to follow the modern petrological trend and reserve the term "grit" for sandstones with angular grains, but this was found to be difficult in practice when classifying sandstones in the field, and led to inconsistencies in field descriptions. Consequently this practice was discarded and classifications were based on grain size only, the limits employed by Reading being adopted. In addition 'Grit' has been retained in the names of such Horizons as the Grit Sills, and does not necessarily carry any petrographical implications.

In the Coal Sills, two or three sandstones or grits are generally present below the Little Limestone, the Low and High Coal Sills, and the White Hazle. Each of them shows wide variations in thickness, and each is locally absent. The lithology varies from fine to coarse grained, the bulk of the rock being made up of quartz grains, with varying, generally small amounts of clay minerals and mica. Some of the quartz shows undulose extination and a slightly biaxial interference figure. Felspar is uncommon and generally consists of plagioclase of the oligoclase - andesine range. The sandstone taken as the High Coal Sill frequently has a capping of poorly fossiliferous ganistroid sandstone, which is an invaluable aid to identification, despite the fact that the White Hazle has a similar capping in Parkin Hush, Hudes Hope.

Dunham (1948,pp.28-29) draws our attention to the existence of a "washout" in the Coal Sills at Coldberry, in Vein F, where 73 feet of sandstone represents the three sandstones. Down the eastern and north eastern slopes of the Flushiemere Beck and Tees valleys, no comparable sandstone is seen, while the situation is similar on the eastern flanks of Hudes Hope. Thick sandstones (but not as thick as that in Vein F and other mine sections) crop out in two waterfalls in the northern part of Hudes Hope, suggesting the proximity of a "washout". Poor sandstone development in Parkin Hush to the south prevents us joining this "washout" belt with that in Coldberry Mines, directly. It may swing either to the east or to the west of Parkin Hush to join the Coldberry channel, or may not join it at all. Sixty six feet of sandstone with 12 feet of interbedded shale represent the Coal Sills group in a sump section in Manorgill North Vein, and this may equally well form the continuation of the channel which occurs in the neighbourhood of the waterfalls in northern Hudes Hope. A "washout" above the Great Limestone in Easterbeck Quarry, Lunedale (see p.p. 126-27) lies due south of the Coldberry channel and may well represent its continuation. It is not strictly accurate to speak of a single Coal Sills channel. If the various thicknesses of the 3 members of the group are plotted it will be seen that at each horizon definite belts occur along which the sandstones or grits are thicker (ribbon development). It is significant that these belts occur along very similar lines at successive horizons, one running along the Flushiemere - Hudes Hope divide, the other from the head of Hudes Hope to Manorgill (see figs. 8a, b, c, and d, p. 345).

Coals are not very well developed, one of 6 inches or less appearing locally above the Low Coal Sill, and one 3-inch coal ocurring in Skears Quarry and How Gill which may be below the Low Coal Sill, but this is not certain.

Generally the Coal Sills form a composite, sometimes confused, single feature, but locally the High Coal Sill forms a separate feature.

The Little Limestone is not well exposed within the area, appearing in situ in only four localities. One exposure occurs in northern Hudes Hope, where 4 feet 6 inches of massive, medium grained, sandy grey limestone (No.171) crops out over a thick sandstone in a waterfall. As much as 30% of the limestone consists of detrital quartz. For the second exposure we must go to Eggleston Burn, 5 miles to the south east, where an 18-inch famped limestone over shales and sandstones regarded as belonging to the Coal Sills, may or may not be the limestone in question (but see p. 124). To the east, the Little Limestone is exposed as 7 feet of limestone which is muddy and fine grained towards the top, but coarser and sandy towards the base. Finally in Shields Beck in Lunedale, it outcrops as a thin sandy limestone in the stream bed, approximately 50 to 60 feet above the Great Limestone. Further information can be obtained from mine sections, the thickness varying from 4 feet at Flushiemere No. 2 mine, to 10 feet at Skears Great Rise. Over the Northern Pennine Orefield as a whole, it varies from 4 feet to 21 feet, with an average thickness of less than 10 feet (Dunham 1948, p.31).

As pointed out by Dunham (1948,p.31), the first sandstone above the Little Limestone is usually called the Pattinson Sill, and this practise has been followed here. It is comparatively well developed in Flushiemere, ranging from a 15 feet fine grained sandstone in the north to a 25 feet coarse, current bedded grit in the south in Bleak Ley Green Hushes. Further south, in the Revelin area, it thins out.

The Firestone Sill, recognised by the presence of the Crag Limestone which caps it (Dunham 1948,p.32), is absent in Flushiemere and the western end of Coldberry Gutter, where the Crag Limestone overlies at least 20 feet of shale (with thin sandstones in the lower part) above the Pattinson Sill. At the eastern end of the Gutter, 7 feet of medium grained, mottled grey sandstone is seen below the limestone, while mine sections testify to its continued development in the various Coldberry mines to the south east and east. It is seen to thicken considerably and coalesce with the underlying Pattinson Sill, so that we have in Skears Great Rise 60 feet of sandstone classed as 'part of the Firestone Sill' directly overlying a 10 feet Pattinson Sill. In Skears Vein F 69 feet of sandstone represents the combined sills, with thicknesses of 62 feet and 68 feet 6 inches in Vein D and the Coldberry and Lodgesike mines respectively. On the eastern flanks of Hudes Hope, in northern Hudes Hope where the group crosses the beck, and in Snaisgill Sike, no significant sandstone developments occur below the Crag Limestone. The situation is, then, that we have a Firestone Sill coming in east of Flushiemere, rapidly attaining a fairly considerable thickness and coalescing with the Pattinson Sill. To the east it attenuates with shale once more.

In Great Eggles Hope, a grit, 13 feet of which is exposed, is upfaulted by the Flake Brig Vein, and was identified by Carruthers (1938) as the Firestone Sill. This is probably correct, although the Crag Limestone is not seen. One of the Knucton Shell Beds does crop out upstream however. Some 58 feet 7 inches of sandstone capped by a 5 inch coal, the Crag Coal, is recorded from Manorgill Mine to the west. No mention of the Crag Limestone is made. No coal which can definitely be correlated with this coal crops out on the surface, but 3 feet of coal, "till bed", and shale are reported above the Firestone in Skears Mine in Vein D. This thick sandstone probably represents both the Firestone and Pattinson Sills and reveals a probable "washout", or ribbon sandstone, east of Hudes Hope. A note on one of the London Lead Company's maps states that the Firestone Sill is absent in the Lodgesike - Manorgill Vein on the Hudes Hope - Great Eggles Hope divide, while Dunham (1948,p.301) states "it is probable that the Firestone, present as a coarse grit in Great Eggleshope, dies out westwards." We seem therefore to have two ribbon sandstones at this horizon, one following a roughly north - south or north north west - south south east course between Flushiemere and Hudeshope Beck, and a second running through Manorgill Mine. The course of this latter is not known; no comparable development occurs in Eggleston Burn to the south, or Stobgreen to the south east. Bearing in mind the similar courses followed at successive horizons in the Coal Sills group, and that the channel between Flushiemere and Hudes at this horizon follows the same course, it would seem reasonable to assume that the Manorgill development continues northwards through the head of Hudes Hope. In Lunedale, the succession is similarly lacking in any notably thick sandstone development (see fig. 8e, p. 345). One thin sandstone with a shelly top, approximately 30 feet above the Little Limestone in Shields Beck, may possibly represent an equivalent horizon to the White Sill of Alston Moor, which has a similar capping (Dunham 1948,p.32), but it is unwise to correlate over this distance, especially bearing in mind the lack of any comparable horizon in the area mapped to the north.

Lithologically the Firestone is variable. In Coldberry Gutter it is medium grained and consists dominantly of quartz, which frequently displays strain shadows and sometimes a slightly biaxial interference figure. Quartzite and plagioclase felspar grains occur. In Great Eggles Hope, it is coarser (up to 2 mm. diam.), and quartz (of a similar nature) is once again the dominant constituent, but felspar, largely corroded, forms as much as 10 or 15% of the rock. Hydrobiotite flakes occur. Clay minerals are present interstitially in both localities and form at least 5% of the rock.

The Crag Limestone is well exposed in Coldberry Gutter where a 3 feet 6 inches limestone is capped by 22 inches of shale and a 30 inches siliceous limestone. Both limestones and the intervening shales may be grouped together as the Crag Limestone. The upper limestone post weathers in a characteristic manner, the middle portion being eroded more rapidly than the remainder of the limestone which is more siliceous. This upper post is again seen in Hudeshope Beck to the north, and a similar limestone crops out in Snaisgill Sike. In Eggleston Burn, just below the mouth of Bell Sike, a 2 feet siliceous limestone outcrops 9 feet above a second limestone, 3 feet of which is exposed in the burn. These two limestones probably represent the twin Crag Limestone (but see pp. 140-42). In Stobgreen Sike, a 6 feet siliceous limestone, approximately 60 feet above the Little Limestone, represents the horizon, or part of it. The overlying beds are badly exposed, so that a second limestone post may be present.

An isolated exposure in the Tees, upstream from Eggleston Bridge, probably represents the Crag Limestone, and consists of an 8 feet crinoidal limestone separated from an upper 6 to 7 feet crinoidal limestone by 4 feet 6 inches of mudstone grading up into a muddy blocky limestone. No associated strata crop out below the Transgression Beds Grit. Finally, in Shields

Beck, a 5 feet crinoidal limestone is succeeded by 8 to 10 feet of fossiliferous, calcareous shale, and a 4 feet muddy limestone. The twin nature is therefore seen to be widespread in this area, and where not seen, may be because of mere non exposure.

Shales up to 35 feet thick (the lower beds being usually fossiliferous) separate the Crag Limestone from the Knucton Shell Beds. These shell beds, first named by Carruthers (1938,p.238) are commonly represented by two thin, frequently calcareous, fossiliferous sandstones, with an abundance of Spirifer bisulcatus group, and other brachiopod casts. They are widely exposed in this area. The thickness and separation of the beds varies, but they are usually between 2 and 4 feet thick, with anything up to 15 feet of shale between them. Shales of varying thickness follow, depending upon the extent of the Rogerley Transgression.

Next in the succession are the Low and High Grit Sills. Westgarth Forster (1809,p. 99) referred to them as the Low and High Slate Sills, while Carruthers (1938,p. 237) preferred the Hunstanworth miners' terms Low and High Grit Sills. Dunham (1948,p.36) refers to their equivalents the Great Sill of Rookhopehead, the Low Grit Sill of Hunstanworth, and the Freestone Sill of the Bollihope Air Shaft. The terms Low and High Grit Sills are retained here, being more in keeping with their lithological character. Ribbon sandstone development is again a conspicuous feature of this group of strata. In Bleagill Sike, a tributary of Flushiemere Beck, the Low Grit Sill consists of 15 feet to 20 feet of coarse grit, while upstream the High Grit Sill comprises only 10 feet of fine grained flaggy sandstone. To the south east the latter forms an increasingly bold feature, but north westwards no such feature occurs, the Low Grit Sill and Transgression Beds Grit being separated by a typical concave shale feature. A small stream below Carr Crags (918316) to the north reveals only 20 to 25 feet of shale between the Low Grit Sill and the Transgression Beds Grit, the remainder of the succession being concealed. In Coldberry Gutter to the south, at least 25 feet of coarse, current bedded grit crops out at the eastern end, belonging to the High Grit Sill. Westwards along the Gutter the grit attenuates and gives way largely to sandy shales and sandstone, so that at the western end less than 15 feet of shaly sandstone over 40 feet of sandy shale with thin sandstone ribs occurs. This westerly attenuation tallies with that reflected in the High Grit Sill feature to the north. The Low Grit Sill outcrops in the western end of the Gutter, but is seen to better advantage a short distance to the south, where at least 20 feet of current-bedded grit has been quarried. In a section for Coldberry and Lodge Sike Mines, i.e. to the east, the Low Grit Sill is reported as being 52 feet thick succeeded by 60 feet of shale and an 8 feet sandstone.

To the north, in Hudeshope Grains, the sill consists of 75 feet of medium to coarse grained, current bedded grit, separated from 40 feet of shaly and flaggy sandstone, the High Grit Sill, by 10 to 15 feet of shale. Exposure down the eastern side of Hudes Hope is generally poor, but in Manorgill to the east, a section from the Middle Level to the Low Level records a 61 feet 2 inches Low Grit Sill followed by 43 feet of shale, 12 feet of sandstone, 18 feet of shale and a 40 feet 8 inch High Grit Sill. Some 18 feet 4 inches of shale separates

Where on map?

the latter from a third, 36 feet thick sandstone which is absent to the west. In Manorgill Quarries, a short distance east, the Low Grit Sill is only 30 feet thick, and upstream in Great Eggles Hope (i.e. north west) both grits are seen to thin, especially the High Grit Sill, while the third sandstone dies out completely. To the south this belt of thick grit development in both horizons can be traced to Blackton Bridge, where the two Grit Sills coalesce to form a single grit at least 100 feet thick in Blackton Beck. The third sandstone is present, attaining a thickness of 20 feet in Wire Gill, and on the western slopes of Great Eggles Hope and Eggleston Burn, but in the Stotley area to the west of Eggleston Burn, it dies out. In Stobgreen the Grit Sills are attenuated, their possible maximum combined thickness being 42 feet. A single grit occurs in Lunedale, with 34 feet of coarse to very coarse grit occurring in a quarry near Hayberry Well (984227), thinning westwards until only 6 to 7 feet of fine grained sandstone is present in Wester Beck.

Not shown on map

The thickness of the strata between the two beds varies from nil in Blackton Beck to over 70 feet of shale and sandstone in Manorgill Mine. A 4 inches coal occurs above the Low Grit Sill in Eggleston Burn. Above the High Grit Sill an 8 inch seam crops out in Great Eggles Hope, a 4 inch coal in Wire Gill, and two coals, a lower 4 inches and an upper $2\frac{1}{2}$ inches, are seen in East Skears Quarry, in Eggleston Burn. Above the Grit Sills in Stobgreen Sike, a 1 inch coal is probably equivalent to one of those above the High Grit Sill elsewhere.

Dunham (1948,p.36) refers to the transgression below the Low Grit Sill as the Rogerley Transgression because it attains its greatest development near Rogerley Intake, $1\frac{1}{2}$ miles east of Stanhope, Weardale. He describes a "washout" belt, $2\frac{1}{2}$ miles wide, lying to the east of the head waters of Great Eggles Hope, transgressing across the Knucton Shell Beds, the Crag Limestone, and even the Firestone Sill in one instance. On either side of the belt the transgression lifts to preserve the Knucton Shell Beds. A second belt has been described, extending from Hudeshope Head to Blackton Bridge, following a north north west - south south east line. The Knucton Shell Beds are nowhere visibly transgressed, with the possible exception of Blackton Bridge, where but one shell bed occurs, 10 feet below the Low Grit Sill. The Manorgill Mine sections show no beds ~~referable to the~~ shell beds, and it is significant that the Low Grit Sill attains the thickness of 60 feet, and is separated from the Firestone Sill by little over 10 feet of shale. Unless the mine sections have been wrongly interpretted, the Low Grit Sill is strongly transgressive here. A short distance to the east, in Great Eggleshope Beck, the transgression has lifted once more to preserve the Knucton Shell Beds, while the Low and High Grit Sill are less well developed. The course of the "washout" beyond Blackton Bridge is conjectural. The most likely line is to the north of Eggleston with possibly a branch given off in a west south west or south westerly direction into Lunedale. By plotting the thicknesses of the grits it is possible to trace ribbon developments up to two miles wide in both horizons, following similar courses (though broader) to the easterly members of the twin channels developed at lower horizons (see figs 8f and 8g, op. 345).

The beds succeeding the Grit Sills and the third sandstone are very variable both in thickness and lithology, but certain marine bands help to correlate the various sections. Carruthers (1938) named a series of calcareous, shelly sandstones above the Grit Sills, the Rookhope Shell Beds and Ironstone. According to H.G. Reading (1954,p. 77) the Rookhope Ironstone dies out near Wester Beck (on the south west margin of the area mapped), and is absent to the east. Nothing which can definitely be allocated to this horizon occurs within the area. Reading identified a thin fossil band in shale cropping out in Wester Beck as being equivalent to the Ironstone, but identification of a limestone lower in the succession in this stream as part of the Lower Felltop Limestone (on lithological grounds - see p. 167) rules this out.

The Rookhope Shell Beds are represented on the eastern flanks of Hudes Hope, north west of Monks, where a thin shelly sandstone crops out a few feet below the Transgression Beds Grit. Some fossiliferous shales below the same grit at the head of Manorgill Sike to the north east may occur above this fossil sandstone which is not exposed. To the east, in Great Eggles Hope, a thin, partially famped limestone in West Rake Hush probably represents the same horizon, but the succeeding beds below the Transgression Beds Grit are much thicker. A 3 feet calcareous sandstone caps the limestone followed by 11 feet of fossiliferous shale, with the grit lying a few feet above. The third sandstone in the Grit Sills group occurs a short distance below. The Rookhope Shell Beds are exposed once more in Wire Gill, a tributary of Great Eggleshope Beck, further east. A 3 feet famped fossiliferous limestone crops out approximately 15 feet below the Transgression Beds Grit. No fossil shales are seen above. Carruthers (1938) reported the presence of the Rookhope Shell Beds in Great Eggles Hope, to the north; fossiliferous sandstones outcrop but they prove to be fault-repetitions of the Knucton Shell Beds. Some fossiliferous shales outcrop anything up to 15 feet below the Transgression Beds Grit near the head of the beck and may be equivalent to those seen above the shell beds elsewhere.

In Stobgreen Sike, the Rookhope Shell Beds take on a very different form. Above the Grit Sills, a 1 inch coal is followed by a variable succession of chert, siliceous limestone, and mudstone, which are referred to the Rookhope horizon. The chert consists of clear, colourless chalcedony and brown chalcedony, which have replaced original calcite forming sponge spicules and other organic fragments, in one case. A second slide of the same bed, shows some original organic calcite remains, the remainder consisting of pale brown and clear chalcedony. The siliceous limestone consists of intimately associated silica and calcite in the ratio of 4 : 1. The calcite is usually more or less corroded and some crinoid ossicles clearly show replacement of calcite by silica. Some pellets and pockets of glauconite and small quartz grains (detrital) occur. This refers to the base of the limestone. The upper part of the limestone consists almost completely of finely crystalline calcite with no silica apart from some small pockets of pale brown isotropic silica, and a few crinoid ossicles preserved in clear chalcedony.

The Lower Felltop Limestone has been removed by the Coalcleugh Transgression in Stobgreen Sike. A similar succession crops out in the River Tees below Eggleston.

The Lower Felltop Limestone is the original "Felltop Limestone" of Westgarth Forster. A thin crinoidal limestone, 6 inches of which is exposed, crops out in Hudeshope Grains. Associated strata between the High Grit Sill and the Transgression Beds Grit are concealed, but the limestone is tentatively classed as the Lower Felltop Limestone, because of the pure nature of the limestone, which contrasts with the lithology of the Rookhope Shell Beds in Hudes Hope and Great Eggles Hope. It may equally well represent the latter marine horizon however. A 4 inch limestone exposed above the High Grit Sill on the southern side of Coldberry Gutter may represent either horizon, as already pointed out by Dunham (1948, p.40), but probably belongs to the Rookhope Shell Beds.

In the left bank of the Tees below Eggleston, opposite Skirtle Bank, the Lower Felltop Limestone is exposed as a twin limestone, consisting of a lower 3 feet 9 inches limestone with two thin shale partings, and an upper 4 feet limestone with a 1 inch parting, separated by 10 feet of shale. The basal part of the lower limestone is very sandy, almost a calcareous sandstone. The basal part of the upper limestone has a characteristic lithology and contains up to 50% detrital material set in a fine grained calcite matrix with a few ill-defined micro fossils. About 70% of the detrital material consists of rounded quartz grains (up to 3 mm. diameter) which display undulose extinction and sometimes a slightly biaxial interference figure. Rounded grains of quartzite are next in importance (15%) followed by microcline (met for the first time in significant amounts), and orthoclase grains, which show all stages of replacement by calcite, (see p. 236). Glauconite is another important constituent, forming up to 10% of the rock. The glauconite occurs both in the form of pellets, with shrinkage cracks infilled with calcite, and in smaller interstitial patches. The upper portion of the top limestone is a normal fine grained grey limestone with crinoid plates, microfossils and other organic debris in abundance.

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The basal limestone~~s~~ is seen in Shields Beck and Wadycarr Sike, retaining its coarse, sandy lithological character. In addition, a limestone identified by Reading as the Rookhope Shell Beds occurs in Wester Beck. It is lithologically identical with the basal part of the upper limestone seen in the Tees (see pp. 167-68), and on this evidence has been identified as belonging to the Lower Felltop Limestone. A few feet below, a calcareous siltstone represents the finer grained lower limestone. Reading (1954,p. 83-4) has drawn our attention to the constant lithological nature of the Lower Felltop Limestones in the Stainmore area, including the Tees below Eggleston, and this seems to add weight to the identification of the limestone on lithological grounds. Dunham (1948,p.41) describes the limestone as a fine grained grey limestone, varying from less than a foot to 6 feet in thickness over the Northern Pennine Orefield.

Above the Lower Felltop Limestone, a series of transgressive beds called simply the "Transgression Beds" by Carruthers (1938) occur. Dunham 1948,p.40) referred to them as the Coalcleugh Transgression Beds to distinguish them from the beds connected with the Rogerley Transgression, and described them as "limonite stained, flaggy sandstones with ganister in places, medium to coarse grained, but rarely becoming grits." Reading mapped three grits (in the eastern part of his area) which he called the Transgression Beds Grits (1954p.80). The name "Transgression Beds Grits" has been adopted for a variable sandstone - grit horizon which occurs over the greater part of the area. The thickness varies from 15 feet in the north west to over 50 feet in the south, near Eggleston, while the degree of coarseness is highly variable, changing rapidly from fine grained to coarse-pebbly in places. It is generally current bedded with the source directions having a strong northerly component. Quartz is again the dominant constituent, but clay minerals may form up to 30% in the coarser grades. Normally the clay minerals account for 5 to 10% of the rock. Quartzite grains make up 8 - 10% in places, while felspar is not conspicuous. The latter is frequently absent, but may form up to 3% of the rock, and is usually corroded. Mica, usually hydrobiotite, can form as much as 3 - 4%. Locally the grit has a calcareous cement, making up 7 - 10% of the rock.

Ribbon development is not very evident, but a second grit or sandstone comes in in the eastern half of the area, first making an appearance in the Eggleston area in the south. To the north, it is first seen in Ayhope Beck in the north east corner of the area, but may be present further west, where erosion has not proceeded sufficiently to expose the relevant strata. In Little Eggles Hope the sandstone is definitely undeveloped, the Transgression Beds Grit being succeeded by no more than 35 - 40 feet of strata below the Upper Felltop Limestone. This sandstone, which is developed between the Upper Felltop Limestone and the Coalcleugh Marine Beds, is probably equivalent to the Hipple Sill (or Low Grindstone Sill), and has been so called. In the area East of Eggleston, this upper bed reaches a thickness of 55 feet of coarse grit, thinning to 25 feet of shaly sandstone in Raygill Beck to the east. Reading's maps of this part of the Tees show the lower grit at Eggleston (the Transgression Beds Grit as mapped in this area) splitting into two beds, this making up his three grits, the pebbly, middle, and upper grits.

In Lunedale, only two grits are present, the pebbly grit having died out. Identification of the lower grit in Lunedale depends upon the presence of a coal in Shields Beck and Wadycarr Sike which Reading correlated with a seam occurring below the middle grit in the Tees south of the area mapped. No coal has been recorded between the Lower Felltop Limestone and the Transgression Beds Grit in the area surveyed, so this correlation, is tentatively accepted. It should be borne in mind that exposure at this level is poor over the area and also that the Coalcleugh Transgression is active and might have removed any such coal. No evidence justifying the separation of the grit occurs within the area surveyed however. The primary surveyors mapped only two grits, with a coal coming in (apparently within the lower grit) beyond the southern limit of the present area, presumably where the middle grit develops as a separate entity.

The Transgression Beds Grit is overlain by the Coalcleugh Coal, which was worked on the summit of Killihope Pass, on Nunnery Hill, and on the fell side south of Coalcleugh (Dunham 1948,p.40). The coal is only seen on the western slopes of Eggleston Burn where 2 feet of grey shale above the grit are followed by 18 inches of grey shale with coal streaks, in Horden Sike. If the Transgression Beds Grit merely splits to form the pebbly and middle grits, then the coal below the latter in the Tees and elsewhere is not the Coalcleugh Coal. If, however, the middle grit is an independant development, above the pebbly grit (i.e. the Transgression Beds Grit) then the coal is the Coalcleugh Coal. Reading correlated the coal in the Tees, Shields Beck, and Wadyearr Sike with the Tanhill Coal. If this correlation is correct, then, depending on whether the middle grit is a completely independent grit or not, the Coalcleugh and Tanhill Coals may be equivalent. In any case, the Transgression Beds Grit is at least in part equivalent to the Kettlepot Ganister of Rogan's Seat, which occurs below the Kettlepot or Tanhill Coal.

R.G. Carruthers (1938) related the transgression below his 'Transgression Beds' to that which he recognised below the Tanhill Grits. Chubb and Hudson (1925) however, considered that the Tanhill Transgression occurred below the Tanhill Coal and Ganister, rather than below the Tanhill Grits. The coal which Reading correlates with the Tanhill Coal is widespread, can nowhere be seen to be actively transgressed, and is known to overlie a transgressive group (the pebbly grit). On this basis he supports the suggestion of Chubb and Hudson. The presence of this transgressive plane strongly suggests that if the pebbly and middle grits are independent formations, and not merely two leaves of a single grit, the Transgression Beds Grit is equivalent to the former, and not the latter.

The extent of the Coalcleugh Transgression in the present area is revealed by the presence or absence of the Lower Felltop Limestone, where this can be proved. The first definite signs of transgression occur north of Low Monks, on the eastern flanks of Hudes Hope, where the Rookhope Shell Beds are succeeded by only 10 feet of shale below the Transgression Beds Grit. The Lower Felltop Limestone has been removed. To the east, in West Rake Hush, the transgression has lifted to preserve 26 feet of beds above the Rookhope Shell Beds, but the Lower Felltop Limestone is not seen. Further east, in Wire Gill, the grit has descended to allow the preservation of no more than 15 feet of beds above the Rookhope Shell Beds, the Lower Felltop Limestone being absent. The latter is also removed in Stobgreen Sike. To the south east, in the Tees, the transgression lifts from Eggleston Bridge, where the Lower Felltop Limestone and the Rookhope Shell Beds are absent, to Black Sills where the lower post of the Lower Felltop Limestone is intact, and continues to lift downstream until the two posts occur, capped by over 11 feet of shales, opposite Skirtle Bank. To the west, in Lunedale, the Transgression Beds Grit proper (the pebbly grit) is not developed, and the Lower Felltop Limestone is present.

The nature of the transgression is unlike that associated with the Low Grit Sill, the Rogerly Transgression, which appears to be largely confined to "washout" channels. The only definite occurrence of the Lower Felltop Limestone, apart from the Lunedale exposures, occurs in an area where the Transgression Beds Grit and associated grits, attain their greatest development - in the Tees below Eggleston. The available information suggests that the transgression is nowhere violent, comparatively speaking, within the area, but rather a general, somewhat irregular transgressive plane. It must be remembered, however, that over large tracts of the area, both the base of the grit and the underlying beds are concealed, so that the extent of the transgression is unknown. If known, the situation in these areas, might modify this concept considerably.

The Coalcleugh Marine Beds as described by Dunham (1948, p.41) consist of shales with marine fossils, above the Coalcleugh Coal. Such shales have only been seen in Little Eggleshope Beck, where 3 feet of soft grey, friable, poorly fossiliferous shales lie directly above the Transgression Beds Grit, no coal being developed. Thickness of beds between the Transgression Beds Grit and the Upper Felltop Limestone is highly variable, with 35 - 40 feet of shales and sandstones in Little Eggles Hope, and 70 - 80 feet in the Eggleston area, including a 55 feet Hipple Sill.

Dunham (1948,p.45) has suggested that the primary surveyors regarded the Upper Felltop Limestone of the Derwent Valley as the equivalent of "famp" number 111 of Westgarth Forster's section. In the present area, the Upper Felltop Limestone is revealed in Redgate Shields (031297) as a composite limestone-sandstone-shale succession, consisting of:

	Ft. - Ins.
Fossiliferous limestone.	1 - 6
Sandstone.	6 - 6
Sandy Limestone) Sandstone)	3 - 0
Limestone and shale, some of the) limestones fossiliferous.)	13 - 0

Outcrops of the limestone usually consist of fossil limestone over sandstone, as in Little Eggles Hope, and Sharnberry Gill, which may either mean that the lower limestones are impersistent, or merely that they do not outcrop because of their thinness. The limestone is frequently haematite stained, and usually sandy. In Little Eggles Hope, it has an oolitic - like appearance, due to the detrital grains (quartz, quartzite and some felspar) which form 30% of the rock. The carbonate, in this case, is siderite, which weathers to give a thick limonite shell. The fossil fauna of the limestone is dominated by the productid Sinuatella sinuata de Koninck.

A band of fossiliferous shale generally occurs 30 - 40 feet above the limestone in the northern part of the area, which may be equivalent to a fossiliferous sandstone cropping out approximately 15 feet above a very poorly developed Upper Felltop Limestone on Barnley and elsewhere in the southern part of the area. A "Fossil Grit" was mentioned in the Mallerstang Memoir (1891, p. 151), but no name was given to a similar horizon on the Alston Block, so Reading (1954,p.119) adopted the name "Fossil Sandstone", as it is generally a sandstone, not a grit in the Stainmore - Cotherstone area. It consists of a calcareous sandstone, grading laterally and vertically into a good limestone, but, within the area mapped, is very poorly fossiliferous, yielding only some indeterminate gastropod or cephalopod shells in the stream near East Barnley (008222). The bed varies from 6 - 13 feet in thickness.

In the northern part of the area, up to 30 feet of shale and sandstone generally follow below the Grindstone Sill, while in the south, where sedimentation in general seems to have been greater, 60 feet or more of shale and sandstone intervene. A 3 inch coal occurs 10 - 15 feet below the fossiliferous shale in Kings Crag (049296) and Cloudlam Beck, in the Sharnberry Gill - Euden Beck area, and a 6 inch coal cropping out some distance above the Upper Felltop Limestone in South Grain Beck probably represents the same horizon.

The Grindstone Sill varies in thickness from 15 - 35 feet from west to east, generally speaking, with local exceptions. The lithology is fairly constant, being normally a fine to medium grained, flaggy sandstone, with a calcareous cement in places, notably the Pallet Crag area (027226). Quartz grains, frequently showing undulose extinction, and sometimes a slightly biaxial interference figure, are the dominant constituents. Felspar, generally corroded, may form as much as 12% of the rock. It is generally micaceous, containing 3 - 4% of hydrobiotite and muscovite normally. Clay mineral content varies up to 30%, but generally constitutes 5 - 15% of the rock. A calcite cement amounting to 50 - 60% of the rock is locally present.

The Pallet Crag area is also notable for the development of coarse grit lenses within the grit, comparable with those present on Bollihope Carrs, Weardale, (Dunham 1948, p.42). The most important newly recorded feature of the sill, however, is the widespread development of a limestone, frequently famped, up to 5 or 6 feet thick, on top of the sill. It is located in places as far apart as Lodgegill Sike in Great Eggles Hope, and Kings Crag, Euden Beck. In Euden Beck one occurrence is fossiliferous. The limestone in Sharnberry Beck is seen to have a lenticular nature, with fine grained limestone grading laterally and vertically into calcareous and non calcareous sandstone.

Beds between the Grindstone Sill and the First "Millstone Grit" naturally vary in thickness because of the transgressive nature of the latter. In the Pallet Crag - Barnley area, however, sedimentation is again thicker, with at least 90 feet of sediments occurring. A marine horizon occurs in certain localities widely spread over the area, varying from poorly fossiliferous shales in Hudeshope Grains, approximately 15 feet above the Grindstone Sill, to a 2 - 4 inches limestone in Pallet Crag Gill, 80 feet above the sill. A 9 inches coal occurs below this horizon in Hudeshope Grains, while a 3 inches coal caps 3 feet 6 inches of fossiliferous shale in Dusty Gill, Great Eggles Hope. A thin micaceous green sandstone crops out below the marine horizon high on the western slopes of Eggleston Burn and Great Eggles Hope, while a similar, though thicker sandstone is seen in Spurlswood Beck, Redmire Gill, and in Pallet Crag Gill below the 2 - 4 inches limestone. Its green colour is due to liberal amounts of chlorite, in flakes and aggregate masses, present in the rock. The usefulness of this sandstone as a marker horizon is somewhat impaired by the occurrence of a similar, though less micaceous sandstone below the Grindstone Sill in some localities. In conjunction with other evidence, however, it is quite valuable. Dunham, (1948,p.42), in discussing the beds above the Grindstone Sill, states that "they include, above Harthope, some greenish micaceous sandstones, with a thin coal."

DETAILED STRATIGRAPHY.

Beds from the base of the Great Limestone to the top of the Little Limestone.

<u>Newbiggin area</u> - Near the confluence of Broperygill Sike and Rowantreegill Sike, 30 feet of blue-grey crystalline limestone (No.338) crop out, representing part of the Great Limestone, the basal portion being concealed. The outcrop is fault-bounded on two sides, the north east - south west Broadley Hill South Vein terminating it on the north, with a downthrow of 15 feet to the north west (Dunham 1948,p.294), while the northern branch of the powerful north west - south east Flushiemere Great Vein cuts it off to the south with a north easterly downthrow of 60 - 100 feet (Dunham 1948,p.295). A band of corals and brachiopods can be seen, but its position within the limestone is difficult to fix because of the nature of the outcrop. The following is the succession recorded at Flushie Mere No.2 Mine (914313) under half a mile to the south:

	Ft.	-	Ins.
Little Limestone.	4	-	0
White Hazle.	18	-	0
Plate and grey beds.	1	-	0
High Coal Sill.	10	-	8
Plate.	1	-	6
Post of sill.	2	-	0
Plate.	8	-	6
Girdle bed.	0	-	10
Coal.	0	-	6
Plate.	13	-	6
Low Coal Sill.	14	-	7
Black bed.	0	-	4
Great Limestone.	62	-	6

The succession in Rowantreegill Sike differs somewhat from this, and the situation is further complicated by gaps in the succession. An 8 feet sandstone outcrops 10 feet above the last exposure of the Great Limestone. Presumably the gap consists of shale, though the sandstone may be thicker, with drift obscuring the remaining thickness. 8 feet separates this sandstone, the Low Coal Sill, from a second, the High Coal Sill, with an exposure of 2 feet of shale. The sandstone is fine grained, buff coloured, amounting to 14 feet thick, and contains fossil fragments in the top few feet. A further gap of 4 feet, followed by 8 feet of flaggy, fine grained sandstone, a 5 feet gap, 12 inches of grey ganister with cauda galli (No.184), and a final gap of 12 feet with some fossil shale (No.185) exposed occur below a sandstone thought to be the Pattinson Sill. The Little Limestone is not seen, to enable definite identification of the various sandstones. It would seem that the White Hazle is either represented by 8 feet of sandstone, or is absent, with the sandstone belonging to the lower High Coal Sill. The former view is adopted, because the High Coal Sill is seen elswehere to have a shelly top, as does the 14 feet sandstone in this stream section. The Little Limestone occurs either in the 5 feet gap immediately above the 8 feet sandstone, or in the gap above the ganister. The various recorded mine sections in this area (see fig. 3a, p. 74) show the limestone directly above the White Hazle, so the former suggestion is probably correct, but a close search failed to reveal any signs of the limestone. Comparison of the stream section and mine section quoted above, affords a good illustration of the variability of the Coal Sills group.

Half a mile south of the sike, the Great Limestone feature emerges from the thick drift of Flushiemere to run southwards just below the 1500 feet contour, having been uplifted by the twin Flushiemere Great Vein. On Bale's Allotment the feature

swings through 90° to run eastwards to Blea Gill. A north east - south west vein has been hushed, to form Bale's Hush, in the Great Limestone. Mineralized limestone is exposed in the upper part of the hush. The limestone, dipping east north east at up to 15° or 20°, is well exposed, but an accurate measurement of the full section is difficult because of the dip, and intermittent exposure. However, the Tumbler Beds are seen to be 18 feet thick, with the limestone below at least 50 feet thick (No.337). Coral bands, with some brachiopods, abound, 12 such bands being seen, although this may not be a strictly accurate picture, because such bands do not appear to maintain a constant horizon, and the bands cannot be traced horizontally for any great distance because of interruptions in the outcrop. The section is remarkably fossiliferous however, comparing very favourably with any other Great Limestone section in this area. Among the forms that it yields are giganto - productids, while one band is seen to consist entirely of an extensive colony of <u>Diphyphyllum lateseptatum McCoy.</u>
Some chert nodules occur in the shale partings of the Tumbler Beds, but none were seen in the limestone itself. The shale partings are also poorly fossiliferous.

Above the Great Limestone, up to 15 feet or 20 feet of sandy shales with some thin sandstone ribs outcrop in the hush, but no thick sandstone is seen. Above the hush, however, three sandstone features can be confidently mapped up to the Flushiemere Great Vein. The two upper sandstones in particular form a prominent, twin, heart-shaped feature, cut off by the fault, and afford a text-book example of the interruption of features by faulting. No in situ sandstone is exposed, but loose blocks of

Not mapped?

fine grained sandstone and medium grained grit abound. The lowest feature is not very prominent, and peters out near the hush; this, coupled with the dearth of sandstone in the hush, strongly suggests that the Low Coal Sill is thinning in this direction from Flushie Mere No.2 Mine, possibly dying out before reaching Bale's Hush. The two higher sandstone features are taken as representing the High Coal Sill and Pattinson's Sill, the White Hazle being absent to the south.

South of Blea Gill, features formed by the Great Limestone and succeeding beds render mapping easy, with some excellent sections afforded in Bleak Ley Green Hush, and hushes to the south east. The full thickness of the limestone is seen, but intermittent exposure does not allow of accurate measurement. The character of the limestone is unchanged, being of a grey or blue-grey colour, generally fine grained and crinoidal, with fossil bands, and up to 15 feet or 20 feet of Tumbler Beds. Signs of mineralization can be seen in the hushes, and the veins probably link up with the three veins seen crossing Bow Lee Beck north of Hell Cleugh (p. 37). It is the succeeding strata that provides the greatest interest. Two sandstones are seen below Pattinson's Sill, the first consisting of 2 feet to 8 feet of fine grained sandstone, the second of up to 16 feet of medium grained sandstone, with intervening shales, the whole totalling up to 65 feet (see fig. 3a, p. 74). The Little Limestone is again not seen, but some loose limestone was found in Bleak Ley Green Hush below the Pattinson Sill. The top 2 feet of the higher sandstone, the High Coal Sill, is poorly fossiliferous, and is followed by some fossiliferous shales (No.335) identical in lithology and fauna with those occurring below the Pattinson

Sill in Rowantreegill Sike. Thus direct comparison and correlation can be made. The Low Coal Sill thickens from 2 feet - 8 feet in 100 yards in a southerly direction and is evidently making a reappearance after a brief absence in the Blea Gill area. The underlying shales decrease in thickness from 5 feet to 3 feet, possibly ~~due~~ owing to compaction. The High Coal Sill on the other hand thins from 16 feet to 13 feet in the same distance, and its feature can be seen to die out completely to the south east. The underlying shales thicken from 8 feet to 30 feet. The shelly top to the High Coal Sill definitely establishes it as the same horizon as the second sandstone in Rowantreegill Sike to the north. No sandstone intervenes between this and the fossil shale seen in both sections, so that the White Hazle is not developed in the Bleak Ley Green Hush district.

A relatively poor feature formed by the Great Limestone runs south eastwards to Red Grooves where the beds are disrupted by the Lodgesike - Manorgill Vein, which downthrows to the south. Exposures in the various hushes in the locality do not reveal useful sections of the succession because of the mine and hush debris, but the Great Limestone, more or less mineralized, is widely exposed and can be mapped with confidence. Above the Great Limestone, the Pattinson Sill affords the only prominent feature, but relatively good sections of the Coal Sills group present themselves in the Red Grooves Hushes. Normal variability is once more evident, but the following succession is representative:

	Ft.	-	Ins.
Pattinson Sill.	20	-	0
Gap.	20	-	0
Fine medium grained sandstone.	15	-	0
Shale and thin sandstones.	15	-	0
Flaggy fine grained sandstone.	3	-	0

	Ft.	-	Ins.
Sandy shale and shaly sandstones.	10	-	0
Grey, fine grained ganister.	12	-	0
Shales.	14	-	0
Great Limestone. (Approximately)	60	-	0

The Low Coal Sill is represented by a 12-feet ganister, but the identity of the remaining sandstones is not clear. The Pattinson Sill presents no problem, as its feature definitely links the Bleak Ley Green Hush and Red Grooves hushes sections. Whether the High Coal Sill is represented by the 3 feet sandstone or by the 15 feet sandstone is not certain. If the former, then the higher 15 feet sandstone represents the reappearance of the White Hazle, which is absent to the north west. Unfortumately no fossil sandstone can be detected at Red Grooves to definitely establish the identity of the respective sandstones. The High Coal Sill feature can be seen to die out towards Red Grooves, so that the 3 feet sandstone may represent this horizon. On the whole it seems best to accept this view and regard the 15 feet sandstone as the White Hazle, but there is no definite evidence to support either view.

South of the Lodgesike - Manorgill Vein, the Great Limestone feature reappears through the drift and, with numerous limestone exposures, can be followed around to the Miry Lane - Hardberry Hill Vein. Stable Green Quarry affords a fair section of the limestone (No.102) 35 feet of blue-grey limestone being exposed. The top 6 feet can be assigned to the Tumbler Beds, with the underlying 15 feet containing bands of corals and brachiopods which are not always parallel to the bedding. The lower 14 feet to 15 feet of the exposed limestone is largely unfossiliferous. The base of the limestone is concealed. Above the Great Limestone, which dips at 3° or 4° to the east in this locality, exposures are very poor. Some rather confused features can be allocated to the Coal Sills, while two largely overgrown quarries north of High Crags (919286 and 920285) afford exposures of 5 feet of sandy black shales dipping east south east at 3°, and of current-bedded fine grained flaggy sandstone (No.57) (probably the Low Coal Sill) dipping south east at 3° to 4°, respectively.

South eastwards from the Miry Lane Fault, the Great Limestone ? [illegible] (downthrown to the south east) forms a well-defined feature, with limestone scars, running through Ravelin Gill and forming Bell ? [illegible] Edge, the feature and outcrops finally disappearing beneath drift approximately 400 yards south east of Cat Gill (949262). ? [illegible] A gorge cut through the Great Limestone along Ravelin Vein reveals only 30 feet of the limestone which is mineralized in places. The limestone (No.271) is normally grey, fine grained and crinoidal, with the basal 1 foot being sandy. The vein, running in a north easterly direction, downthrows 6 feet to the north west. The top of the limestone is not revealed, but above the gorge, in Brokersgill Sike east of Ravelin Shop (925274), a good section of the Coal Sills is exposed:

	Ft.	-	Ins.
Fine grained buff sandstone.	4	-	0
Sandy buff shales and sandstones.	5	-	0
Sandy black shale.	0	-	4
Ganister.	2	-	3
Fine grained buff sandstone.	10	-	0
Sandy black shale.	0	-	6
Poor coal.	0	-	3
Sandy micaceous shales and sandstones.	10	-	0
Fine grained, flaggy micaceous buff sandstone.	4	-	0
Sandy black shale.	1	-	4
Fine grained flaggy micaceous buff sandstone with black shale parting.	7	-	0

The lowest sandstone must be regarded as representing the

Low Coal Sill, or part of it. No Little Limestone is seen in situ to delimit the Coal Sills group, but some highly siliceous, shaly fossiliferous limestone (No.237) was found on an old tip from a level above the upper 4 feet sandstone, indicating that the limestone is present above the sandstone, although it is not seen in outcrop. On this basis, the 4 feet sandstone, is regarded as representing the White Hazle. The identity of the remaining sandstones is not certain, and unfortunately no fossil sandstone is seen. The 2 feet 3 inch ganister may be of some significance in this respect however, and it seems preferable to regard the 10 feet sandstone and overlying ganister as representing the High Coal Sill, rather than the underlying 4 feet sandstone. The latter may be merely an upper leaf of the Low Coal Sill, or a lenticular sandstone, development. The 3 inch coal is the first surface outcrop of any coal in the Coal Sills so far met with, and is undoubtedly equivalent to the 6 inch coal recorded at Flushie Mere No.2 Mine, 13 feet above the Low Coal Sill. This would seem to lend weight to the suggestion that the High Coal Sill is represented by the thick sandstone in Brokersgill Sike.

The Coal Sills, as a group, form a prominent north west - south east feature above the Great Limestone from High Ravelin House (923278), to Middle Side, where the drift sweeps up from below Bell Edge to form a thick blanket on Tinkler's Allotment. In Cat Gill, the Low Coal Sill is exposed as a fine grained sandstone dipping south east at 8^{o} over some black shales. North of Ravelin Shop, Ravelin Vein (down 6 feet north west Dunham 1948,p.302), Ravelin Old Vein (down 14 feet south east, Dunham 1948,p.302), a northern branch of the latter (down 21 feet south east, Dunham p.302), and the Miry Lane - Hardberry Hill Vein (changing throw to 21 feet to 25 feet down on north west, Dunham,p.302) all run in a north east - wouth west direction presenting a confused run of features, but the Coal Sills feature appears to be singularly unaffected by all but the Miry Lane fault. In this connection however, the Ravelin Old Veins appear to die out before reaching the Great Limestone, so that the throw in the Coal Sills where they outcrop is probably too small to make any visible impression on the feature. In the case of the Ravelin Vein, the throw of 6 feet to the north west again makes no visible impression on the Coal Sills, while an overlying sandstone feature, probably the Pattinson Sill, is thrown out of line.

Compared with sections to the north, the Coal Sills present a more confused picture, with an extra sandstone and less well-defined sandstone horizons. Thick drift over Tinkler's Allotment obscures the Great Limestone - Coal Sills section over Middle Side, and the western side of Hudes Hope below Coldberry, so that it is to the eastern side of Hudes Hope that we must look for further surface information.

<u>Hudes Hope</u> - In Snaisgill Sike the stream cuts down through 59 feet of limestone (Nos. 6, and 74) forming an impressive rocky gorge. Details of the Great Limestone can be seen in the appropriate section in figure 2 (p. 74). Rock debris largely covers the accessible sections so that accurate measuring of the Tumbler Beds is difficult, but they appear to be just over 9 feet thick. The limestone is typically blue-grey, fine grained, and crinoidal in places, containing 2 thick coral - brachiopod bands which are not parallel to the bedding, and which tend to converge

to the south west of the section. The upper 16 inches thick band appears to consist exclusively of rolled clisiophyllid corals, while the lower 20 inches band contains both corals and latissimoid productids, with the latter slightly in the ascendancy.

Immediately west of the old limestone quarries on the eastern bank (952267), High Dyke Vein, downthrowing 7 feet to the east, further south (Dunham 1948, p.307), crosses the stream causing the steep 20° dips in the Tuft previously mentioned (p. 53), and revealing a zone of up to 70 feet of limonitized limestone (Dunham, 1948, p.307). The vein is split into two branches, the northern branch of which rapidly peters out, while the southerly branch probably continues north westwards to meet the Aukside Vein near the mouth of How Gill. An old level (950268) was driven south south east into the southern side of the valley to work the High Dyke and Holm Head Veins (Dunham 1948, p.307). Southwards from Snaisgill a feature enables one to map the limestone confidently for 170 yards before it disappears beneath drift.

Upstream, and in the banks of Snaisgill Sike above the Great Limestone, good sections of the Coal Sills are available (Fig. 3 p. 74). The Low Coal Sill is revealed as a limonite-stained, medium to coarse grained, grey-buff grit, from 4 to 8 feet thick. 4 feet to 5 feet of sandy black shale, with some thin grit ribs separate this from the High Coal Sill, which is a fine grained, micaceous, limonite-stained, grey grit, of 4 feet thickness. A third, 11 feet 6 inches, largely massive (but shaly in places) grey, micaceous ganistroid sandstone (No.7) probably represents the White Hazle. No sign of the Little Limestone is seen, although Carruthers (1938) records a 6 feet limestone, which he identified as the Little Limestone, "10 fathoms above the top of the Great Limestone". The Crag Limestone, 5 feet 6 inches thick, appears upstream (956270), roughly 60 feet to 70 feet above the Great Limestone, but Carruthers reports the Crag Limestone as measuring only 9 inches in Snaisgill, with 5 feet to 6 feet of "lime-plate" approximately 15 feet above (? the upfaulted Crag Limestone). It appears that Carruthers has misidentified this limestone, whose identity is confirmed by the overlying Knucton Shell Beds. A road bridge over Snaisgill (954269) may possibly conceal an outcrop of the Little Limestone - it would form a good foundation for the bridge which would otherwise seem to be built on shales, which outcrop a few yards above and below the bridge. This, of course, is highly conjectural, however.

Northwards from Snaisgill the succession is masked beneath drift until we reach two hollows east of Skears Limekiln. The Great Limestone outcrops in both of them, while the northern hollow lies in line with the Aukside Vein, an old lead level testifying to its presence. A little to the north, Skears Quarry reveals 44 feet 4 inches of limestone, the top 24 feet of limestone and shale partings representing the Tumbler Beds. Five fossil bands containing corals and brachiopods occur, one in the lower post of the Tumbler Beds, the remainder in the top 10 feet of the solid limestone. The top band appears to contain only corals, the lowest band only brachiopods, while the remaining bands contain both, with corals predominant. Above the limestone, 14 feet 6 inches of shale with thin sandstones, and a 20 inch ganister capped by a 3 inch coal occurs. This coal may be equivalent to that met with in Brokersgill Sike,

Plate 5.

The Great Limestone, Jack Scars, Hudeshope Beck. The top of limestone, surmounted by shale, occurs near the top of the quarry section . The base, overlying the Tuft, is seen just above stream level.

above the Low Coal Sill. If this be the case, then the Low Coal Sill is represented by a 20 inch ganister.

The Great Limestone can be traced accurately upstream on the left bank, through numerous outcrops, until Low Skears Mine, where the north west - south east Hall's Vein throws it down 60 feet to the north. The base of the limestone on the north, can be seen lying against the shaly sandstone representing the Quarry Hazle at this point, south of the fault. No signs of mineralization can be seen at the surface. For a distance of 270 yards upstream, Hudeshope Beck runs through a steep-sided, rocky, meandering gorge, cut through the full thickness of the Great Limestone, with the valley opening out at either end. The northern end of the gorge is likewise fault-bounded, this time throwing down to the south 10 feet to 15 feet. Dips in the gorge are easterly and up to 5°, but midway between the faults, a shallow south-facing monocline brings the base of the Great Limestone down to, and below, stream-level for approximately 80 yards, giving the outcrop a distorted "H" shape in plan view. Excellent sections of the Great Limestone are afforded, particularly in the old quarry north of Hall's Vein (fig. 2, p. 74). There, sections show lack of persistence in horizon of the numerous fossil bands. Up to 60 feet of limestone occurs, with the top 26 feet or more, belonging to the Tumbler Beds in the Quarry. Insufficient exposure in the stream banks renders full and accurate measurement of the Tumbler Beds impossible. In the quarry, 10 feet of shale are capped by a 5 feet medium grained, micaceous sandstone, representing the Low Coal Sill, or part of it. No coal is seen. The quarry is terminated on the north by a small east - west fault throwing down a few feet to the north.

North of the gorge, the Great Limestone can be traced northwards to a hush cut along the line of Skears Old Vein, throwing 10 feet to 15 feet down to the south. Dips of 5° east were recorded in this hush. The limestone is mineralized, with limonite-stained, crystalline limestone well in evidence. Northwards from here to Lodge Sike Farm (949293), exposure of the limestone is largely confined to the network of hushes, including Hulergill Sike, Marlbeck Gutter, and the hushes to the north of ?l? this cut along the east north east Marlbeck "B" Vein which downthrows 24 feet (Dunham, p.306). An east - west vein runs in the lower reaches of Marlbeck Gutter, opposite Marlbeck Mine, and has been worked, together with the other veins, by an old level (950287). In the intervening country between the hushes, drift obscures most of the solid geology.

The most useful section of the Coal Sills occurs in the hush along Skears Old Vein. 4 feet of black shale separate the Great Limestone (of which 15 feet is exposed), from the Low Coal Sill, represented by 8 feet of fine to medium grained sandstone. The High Coal Sill follows 3 feet to 4 feet of shale, and consists of 7 feet of fine grained sandstone, followed by a gap of 15 feet and a 10 feet sandstone probably the White Hazle. No sign of the Little Limestone occurs, but a gap of 50 feet is followed by 4 feet 6 inches of flaggy and shaly micaceous sandstone and a 2-inch fireclay below the Crag Limestone.

In the hush north of Marlbeck Gutter, a gap of up to 40 feet follows the Great Limestone, of which 20 feet of limestone, mineralized in places, is exposed. After the gap, ganister, ganistroid sandstones, shales, and a 2 inch coal are seen below the Crag Limestone. The Little Limestone is once more not exposed, but the 40 feet gap seems just sufficient to house an attenuated Coal Sills group.

On the west bank of Hudeshope Beck, thick drift masks all the solid geology except for a small limestone exposure near the top of the Great Limestone in Clubgill Sike (947280), the Great Limestone in Skears Scars, and certain exposures in How Gill. Here, a total of upwards of 50 feet of the Great Limestone is revealed, though precise measurement of details concerning the Tumbler Beds, fossil horizons, etc., is not possible. Dips of 15^{o} east south east, and 15^{o} - 20^{o} south east, have been recorded near the confluence of How Gill and Greenwell Sike (944271) indicating a disturbance in the immediate vicinity, though whether it is faulting or simple folding is not clear. Upstream, near the confluence of How Gill with a small tributary, 5 feet of alternating shale and sandstone with a 3 inch coal, are exposed, 10 feet above the Great Limestone. Above these beds, a 10 feet fine to medium grained, buff, micaceous sandstone occurs, followed by 15 feet of sandy, micaceous shales with two thin micaceous sandstones of 2 feet and 4 feet, capped by 8 feet of sandstone (No.5). The sandstone is flaggy and micaceous, the top 18 inches being ganistroid and containing small limonite patches which probably represent fossil fragments. This suggests that the sandstone represents the High Coal Sill, with the Low Coal Sill being represented by the 10 feet sandstone below. If this be so, then the 3-inch coal comes below the Low Coal Sill, and it would seem best to regard the 3-inch coal at Skears Quarry as occupying a similar position. Alternatively it may be regarded as occurring above the Low Coal Sill (possibly occurring in the 10 feet gap above the Great Limestone) with the overlying sandstones representing the High Coal Sill and White Hazle respectively. The nature of the top 18 inches of the highest sandstone encourages one to regard it as the High Coal Sill however. Drift obscures the higher strata.

Mine records from various shafts in the Hardberry Hill area throw light on the Coal Sills development to the west. Thus in the Westmost Skears Mine in Vein D (fig. 3a p. 74) a 7 feet Little Limestone overlies an 81 feet 6 inches sandstone representing the Low Coal Sill, High Coal Sill, and the White Hazle, separated from a 66 feet Great Limestone by 9 feet of shale. This presents a vastly different picture from the exposures in Hudes Hope, and the Newbiggin area. Moving in a north north westerly direction we get the following figures : Skears Mine in Vein E, 11 feet 9 inches of shale capped by a 24 feet 9 inches Low Coal Sill, 2 feet 6 inches shale and a 39 feet 9 inches High Coal Sill beneath 39 feet of drift, possibly situated slightly westward of the "washout" mentioned by Dunham (1948,p. 29). Skears Mine in Vein F would appear to be situated within the washout, with a 6 feet Little Limestone capping 79 feet of sandstone representing both Coal Sills and the White Hazle, with 6 feet of shale above a 66 feet Great Limestone. In Skears Great Rise, the Little Limestone is 10 feet thick and caps a White Hazle only 2 feet thick. 8 feet of shale underlie this, with a 10 feet sandstone, representing the High Coal Sill, above 20 feet of shale, and the Low Coal Sill and shale totalling 20 feet. The Great Limestone amounts to 70 feet thick. Skears Great Rise would also appear to be on the western flanks of the washout. Finally at Coldberry and Lodge Sike, the Little Limestone is

5 feet thick and caps a combined White Hazle/High Coal Sill totalling 8 feet and 38 feet respectively, (no shale parting is recorded). 8 feet of shale overlies a 15 feet thick Low Coal Sill, with 3 feet of shale separating the latter from a 60 feet Great Limestone. Where exactly this section is taken from is not clear, but Lodgesike Mine seems most likely, with the section situated near the eastern edge of the washout channel. To the west, in the Newbiggin area, no comparable sandstone development occurs, and each of the three sandstones is seen to thin or die out completely in places. To the east, in Hudes Hope, the sandstone development is again seen to be poor in comparison; the "washout channel" appears, therefore to run in a roughly north - south direction between these two areas, although the details of the path it follows are obscure, (see pp. 79-80).

The Lodgesike - Manorgill Vein is exposed in Longmire's Gutter 1500 feet north north east of the junction with Hudeshope Beck. It brings the Great Limestone, on the north, in contact with shales and sandstones which Dunham (1948,p.301) suggests might be near the horizon of the Little Limestone. No mineralization is seen. North of the fault, the Great Limestone, coarsely crystalline (No.68), dips north west at 10° below interbedded shales and sandstones. From here it can be traced through the medium of shake holes and as a prominent feature, to Racketgill Sike, the base of the feature maintaining a constant horizon on the 1,250 feet contour. Upstream from here, good exposures facilitate easy mapping of the limestone until the base crosses the beck 140 yards north of the mouth of Coving Sike (937305). The limestone forms the floor of the beck for just over 340 yards to the north. Down the right bank of the stream, the limestone is even better exposed, forming the continuous Newberry Scar for over 900 yards downstream. Beyond this a prominent feature runs for almost 200 yards to the south before drift obscures the solid geology, and the Great Limestone is lost sight of until exposures in some hushes north of the Lodgesike - Manorgill Vein. The full thickness of the limestone cannot be measured in these scar exposures, but an estimated 60 feet occurs. The limestone is of a normal blue-grey, fine grained nature, with fossil bands, and with 30 feet of limestone and shale partings belonging to the Tumbler Beds, the latter being fully exposed in Parkin Hush (937303).

Parkin Hush, up to 400 or 500 feet south of Coving Sike, has been cut along the line of an east - west vein downthrowing 12 feet south. The unproductive Racketgill Vein has also been hushed on the left bank of Hudes Hope in the Racketgill Hushes. Parkin Hush gives a good section of the beds overlying the Great Limestone:

	Ft.	-	Ins.
Poorly fossiliferous buff, fine grained sandstone.	3	-	0
Black carbonaceous shale.	12	-	0
Fine grained ganistroid sandstone, fossiliferous at the top.	10	-	0
Black shale.	10	-	0
Ganister.	4	-	6
Fine grained black shale with plants.	7	-	0
Fine grained sandstone.	2	-	2
Shale with plants.	11	-	0
Tumbler Beds.	30	-	0

It is not clear which sandstone may represent the Low Coal Sill, the 2 feet 2 inches sandstone, or the 4 feet 6 inches ganister, but the 10 feet ganistroid sandstone with some fragmentary fossils at the top probably represents the High Coal Sill. The highest sandstone, is also poorly fossiliferous and confuses the issue slightly. There is little doubt that it represents the White Hazle however, an assumption that is strengthened by the presence of loose blocks of haematite stained limestone up to 3 feet thick directly above the sandstone, which probably represent the Little Limestone.

Upstream the Coal Sills group is well exposed in two Waterfalls:

		Ft.	-	Ins.
Massive, sandy, medium grained grey limestone.		4	-	6
Fine grained, flaggy, buff sandstone.		25	-	0
Sandy shale.		2	-	6
Sandstone.		0	-	12
Silty, limonite-stained, black shale.	10 ft. to	12	-	0
Micaceous sandstone, shaly in places.		20	-	0
Gap.	3 ft. or	4	-	0
Great Limestone.	(Approximately)	60	-	0

This presents a very different picture from that in Parkin Hush, and is evidently situated nearer to a washout channel. Only two sandstones occur between the Great and Little Limestones. The Low Coal Sill has thickened considerably in a distance of 750 yards, with a second thick sandstone coming in approximately 15 feet above. Whether this represents the White Hazle, or the combined White Hazle/High Coal Sill is difficult to say. One is left with four alternatives:

1) The lower sandstone represents both Coal Sills with the upper one representing the White Hazle.

2) The upper sandstone represents both the High Coal Sill and White Hazle.

3) The High Coal Sill is represented by 1 feet of sandstone, or is absent.

4) The White Hazle is absent.

In previous sections with thick sandstone developments, the uppermost of two thick sandstone, has been regarded as representing the combined White Hazle and High Coal Sills, and it seems more consistent to adopt this practice here. The one undisputable fact, is that the whole section represents the Coal Sills group, as proved by the presence of the Little Limestone. The latter is a 4 feet 6 inches thick medium grained, sandy, buff grey limestone with some crinoid debris (No.171).

A Sump section in the Manorgill North Vein gives some useful information concerning developments to the east of Hudes Hope:

	Ft.	-	Ins.
Little Limestone.	2	-	6
White Hazle.	28	-	6
Shale.	6	-	7
High Coal Sill.	21	-	9
Shale.	5	-	4
Low Coal Sill.	15	-	7
Shale.	7	-	10
Great Limestone.	57	-	6

The three Coal Sill sandstones are reasonably well developed, better so than on the eastern flanks of Hudes Hope, and may possibly occur near yet another "washout" channel, but of course there is insufficient evidence to justify stating that this is so. Dunham (1948,p.38) figures a Coal Sills "washout" extending east north east - west south west from Cornish Hush to Coldberry. The sections from Parkin Hush and the beck strongly suggest a roughly north - south direction for such a "washout". This Manorgill development might represent an independent "washout", which may link up with the one in Hudeshope Beck, leaving the Coldberry development as a separate one running in a more north westerly direction, between Flushiemere and Hudeshope Beck.

<u>Country east of Hudes Hope</u> - East of Hudes Hope, drift obscures the Great Limestone from High Dike (950262) to Sun Bank (970252), a distance of approximately $1\frac{1}{2}$ miles, except for a poor exposure of limestone 200 yards west of Stanhope Gate Farm

(955257), and a feature stretching for 260 yards south of the farm. A prominent feature formed by the Coal Sills runs from High Beverley (953259), to a point below East Thatch Lee (963256), the base of which has been taken as marking the top of the Great Limestone. From a conjectured height of approximately 960 feet O.D. at High Dike, immediately south of Holm Head Vein, the base of the limestone descends to 800 feet O.D. at Sun Bank, where poor exposures reveal a light-grey crinoidal limestone (No.235). Large blocks of limestone in Howgill Sike and the stream to the west, point to the proximity of the limestone, although it is not seen in situ. Some loose blocks in Intake Sike above the 800 feet contour suggest its presence nearby, although drift once more blankets any in situ limestone.

An old shaft was sunk north of High Beverley to work coal, but the seam is not exposed at the surface. At Crags (954262), an old quarry reveals at least 18 feet of massive coarse-grained cream grit (No.8), with pieces of loose shelly sandstone in the rubble and soil on top of the grit, the beds dipping east north east at 8°. A feature, with another old grit quarry, runs northwards to the High Dike Vein. This feature also runs prominently east south eastwards as far as Stotley Hall, with good grit exposures in old quarries south east of Crags (955261), north and north east of Gill Harn (957259), in a stream north of West Thatch Lee (961257), and in Howgill Sike, where 18 feet of massive buff grit (No.25) dips east south east at 8° to 10° over grey silty shales. Finally, it is exposed in an old quarry (971255) at 10 feet of massive, coarse-grained grit with some shale partings and capped by 20 inches of ganstroid sandstone and a 2 feet fine to medium grained fossil sandstone (<u>Spirifer</u>

<u>bisulcatus gp.</u> (J. Sow.)) dipping south east at 20°. The question arises as to which sandstone it is. The Primary Surveyors mapped it as the Firestone Sill, with the fossil sandstone presumably representing a sandy facies of the Crag Limestone. No corresponding sandy facies has been located elsewhere in the area, and as Carruthers points out, the Firestone is not present in Snaisgill, 1/4 mile or greater of a mile ¼ of a mile north of the exposure north of Crags. A fossil sandstone has been located on top of the High Coal Sill in many instances, and on this basis it would seem appropriate to correlate this grit with the High Coal Sill, which is represented by a 4 feet grey sandstone in Snaisgill Sike.

Below this grit, in a stream running into Intake Sike, 5 feet of poorly fossiliferous black shale with some brachiopods (<u>Chonetes cf. hardrensis</u>) are exposed, and, closely above the conjectured position of the Great Limestone, some thin grey grits and sandy grey shales. This poor marine horizon has not been met with before in this area.

A north north west - south south east fault, downthrowing approximately 150 feet to 200 feet to the east has been mapped east of the grit quarry near Stotley Hall. The high dip of 20 feet in the grit in itself suggests movement (a dip of 18° north is seen in some sandstone above the Iron Post Limestone in Intake Sike, near the conjectured position of the fault). At Whistle Crag, 30 yards south east of the quarry, 10 feet of coarse, pebbly current bedded grit (No.91) outcrop, and were identified by the Primary Surveyors as the Firestone Sill, and a continuation of the grit in that quarry. Closer examination of the Whistle Crag Grit (which is apparently horizontal) reveals that it is lithologically different, being pebbly, distinctly current-bedded and less compact. Moreover the fossil sandstone is missing, although this could be explained by simple non-exposure. This grit, however, can confidently be mapped across Foggerthwaite to Bell Sike and thence linked up with the High Grit Sill in Eggleston Burn.

Below Whistle Crag, a feature strewn with very large blocks of coarse grit can be traced south eastwards, with in situ grit outcrops, to Foggerthwaite Quarry (976248). It is, of course, the Low Grit Sill, and at the quarry is visibly upthrown approximately 10 feet to the south, by an east - west fault occupied by a member of the Cleveland Dyke system. Thence the grit can be traced to Eggleston Burn.

Approximately 150 feet below the Low Grit Sill at Foggerthwaite, and south of the fault, the Great Limestone has been quarried in Red Scar Quarry (976246), now largely overgrown, but still revealing up to 30 feet or more of the limestone (No.78), with some coral bands. It is readily linked with an old limestone quarry 160 yards to the north west and some limestone outcrops which extend for 70 yards up to the east - west fault which brings down a 6 feet massive grit, probably one of the Coal Sills, to the same level. North westwards from Red Scar Quarry to the east - west fault, the Great Limestone has maintained a fairly constant level, on or just below the 700 feet contour. The Primary Surveyors had simply linked up the Great Limestone here with the Sun Bank exposures, invoking only a fairly high dip. The east - west fault is in direct line with the conjectured east - west fault letting down the Great Limestone outlier at Laky Hill to the west (see pp. 45-6), where 25 feet of limestone with some fossil bands dip north east at 18°. The fault here involves a downthrow of between 150 feet and 200 feet to the south. If, as is highly probable, these faults are one and the same, then there has been a fairly rapid change of throw. This, however, is easily explained by the Intake Sike Fault, the easterly downthrow of which would simply account for this change in throw of the east - west fault.

100 yards south of Red Scar Quarry, the 5 feet thick Tuft which dips east south east below the quarry, is seen to dip steeply south west at 28° in the bed of the Tees. This may mean that the north north west - east south east fault continues beyond the east - west fault, passing nearby, but apart from this there is no evidence, because of the alluvial covering.

Drift and alluvium conceal the solid geology across Egglesburn, but in Eggleston Burn, for a distance of 370 yards above, and 100 yards below Egglesburn Bridge (989240), the top 10 - 15 feet of the Great Limestone is exposed in the stream. 100 yards below the bridge, the limestone, blue-grey, crystalline, and veined with calcite, appears to dip north north west at 60°. Unless this is landslip material, which seems highly unlikely (in any case it cannot have slipped far ~~anyway~~) the high dip suggests the proximity of a fault, but its position and direction cannot be ascertained with any certainty, and in view of the possibility of landslip, has not been mapped.

Upstream, the limestone crops out frequently, and approximately 160 yards east south east of Bog House (991244), 6 feet of massive, crystalline limestone with corals, dips north east at 10° below some sandy micaceous shales and sandstones. A good succession up to and including the Little Limestone is seen between this point and the footbridge 200 yards south of Blackton

Bridge (989249):

	Ft.	-	Ins.
Silty grey shale.	3	-	0
Sandy, micaceous famped limestone.	1	-	6
Sandy, micaceous, limonite stained grey shale.	3	-	0
Sandy, shaly, limonite-stained limestone grading laterally into sandstone.	0	-	9
Sandy shale and shaly sandstones.	2	-	0
Fossiliferous, famped sandstone. 1 inch to	0	-	3
Ganistroid sandstone.	1	-	6
Silty shale.	2	-	0 ?
Ganistroid sandstone.	2	-	6
Gap.	2	-	0
Fine-grained, flaggy sandstone, shaly near base.	13	-	0
Grey micaceous shale.	1	-	0
Fine-grained, flaggy, ripple-marked sandstone.	4	-	0
Sandy micaceous shale.			

The identity of the various sandstones is somewhat obscure. The 18 inch famped limestone may be the Little Limestone. The 4 feet sandstone grades up into the 1 foot thick micaceous shale, which in turn passes up into the 13 feet sandstone, so these might feasibly be grouped together as the Low Coal Sill. The ? 18 inches ganistroid sandstone capped by the thin fossil sandstone (No.85) may represent the High Coal Sill, but these supposition cannot be definitely proved. Alternatively, the 4 feet and 13 feet sandstones may be regarded as the Low and High Coal Sills respectively.

The final exposure of these beds in Teesdale is met with in Stobgreen Sike near Town Head (003238), the intervening country being drift covered. The beds occur as a faulted inlier between the two branches of the Eggleston Fault. The Great Limestone is not seen, though its conjectural position lies south of the road at Town Head. The Little Limestone however is exposed as 7 feet of limestone, muddy and fine grained at the top, and becoming coarser grained and sandy towards the base (No.263). Below, 8 feet of silty, micaceous shale overlie a 4 feet grey, fine to medium grained, poorly fossiliferous ganister (no.262) dipping

Why not shown on map?

north at 26° into the east north east - west south west Northern Eggleston Fault, which is further split into two branches approximately 240 yards to the east. This poorly fossiliferous ganister may be equivalent to the ganister with a richly fossiliferous sandstone capping in Eggleston Burn. 5 feet of sandy, micaceous, grey shale are exposed below.

Lunedale - Immediately south of the still active northern arm of the Teesdale Fault, the upthrown Great Limestone is well exposed in Banklands Quarry (971230), extending on both sides of Bail Hill Road, for a total distance of 430 yards. Details of the succession are provided in fig.2, p. 74 . The base is not seen, but 20 feet of limestone with thin shale partings are assigned to the Tumbler Beds, overlying up to 40 feet of limestone. A coral-brachiopod band varying from 3 feet to 4 feet 6 inches thick, is situated approximately 14 feet below the Tumbler Beds. The limestone, which is grey or blue-grey and generally crinoidal, dips almost due south at 11° to 14° into the Stainmore Syncline. At the eastern end of the quarry, a small north east-south west fault throws up the limestone 6 feet to the east, against 7 feet of black silty shale which cap the limestone on the west. West of the quarry the boundaries of the limestone are conjectural beneath the drift cover, but two small quarries north west of Banklands Quarry, and a shake-hole 100 yards south east of Stoophill House (961230), serve as checks on its position. Almost immediately west of this shake hole, a west north west - east south east fault, downthrowing to the north east has been mapped. An old quarry (958228) shows the base of the Great Limestone overlying the Tuft, dipping south east, at a height of over 1000 ft. O.D., in a drumlin-shaped feature which itself dips eastwards to disappear beneath the drift at Greenrigg Lane, near the shake hole. In conjunction with evidence afforded by the Grit Sills to the south east, faulting seems the best explanation of these facts in preference to a fairly steep downfold. Consideration of respective levels of the limestone has led to the mapping of a conjectural north - south fault downthrowing west, 60 yards west of the old quarry mentioned above.

To the west, the West Pasture Road quarries give further good sections of the limestone (No.310). The easternmost quarry reveals up to 10 feet of Tumbler Beds over 40 feet 6 inches of limestone with two thin shale partings (see fig. 2, p. 74) and one coral-brachiopod band. Some chert nodules were also found in the limestone in this quarry. The base is not exposed so that the full thickness is not known. The beds dip almost due south at 8°. Between this quarry and the quarries to the west, a north west - south east vein (which may conveniently be called the West Pasture Road Vein) throws the limestone down a few feet to the south west. It has been worked from an old level, and two shafts have been sunk along it. It is not seen at the surface.

Up to 21 feet of Tumbler Beds are exposed above 10 feet 6 inches of limestone with no fossil bands in the middle quarry, while the westernmost quarry reveals only 12 feet of Tumbler Beds over 15 feet of limestone with a 1 - 2 feet fossil band containing brachiopods and a few rolled corals, situated 16 inches below the Tumbler Beds. The beds in these quarries dip south south east at 11 to 15°. The disparity in thickness of the Tumbler Beds may be due to non exposure, but in the next exposure at Easterbeck Quarry (944223), the Tumbler Beds and most of the underlying limestone appear to be absent. On the shores of the Grassholme Reservoir, near the flooded mouth of Easter Beck, a medium grained buff sandstone outcrops (apparently in situ) a few feet below the Great Limestone. Above this, 16 feet of fine grained limestone are followed by 3 feet of limonite stained, black shale, a 2 to 3 inches poor coal, 1 feet of fine grained fossiliferous (<u>Lingula mytiloides</u> J. Sowerby) shale (No.324), and finally a 20 to 25 feet medium grained buff sandstone, the Low Coal Sill. If, as appears probable, the Tuft is in situ, then the greater part of the Great Limestone was eroded before ~~prior to~~ the deposition of the shales, coal, and Low Coal Sill. The beds dip south east at 8°.

Shields Beck reveals nothing between the Great and Little Limestones. The latter is probably represented by a thin sandy limestone outcropping in the stream bed approximately 50 to 60 feet above the Great Limestone. In some old quarries south of Banklands Quarry (970229), a medium grained sandstone, 3 feet or 4 feet of which is exposed, is possibly the Low Coal Sill. Nothing further is seen of the Coal Sills group between Shields Beck and Easterbeck Quarry, and if there were any significant sandstone developments comparable to that in Easterbeck Quarry one would expect such developments to come to light somewhere, especially bearing in mind the fact that the drift cover is sporadic east of the West Pasture Road quarries. It seems more than likely that the Coal Sills sandstones are but poorly developed in this part of Lunedale, apart from the Easter Beck development which must be regarded as a local "washout", possibly linking up with the Coal Sills "washout" at Coldberry.

The final exposure is in Lonton quarry (960244), where 14 feet of massive, fine grained grey limestone crops out, dipping east at 15°. No in situ fossil band is seen, but some loose blocks of limestone with clisiophyllid corals (one showing markedly dilated septa - No.26.) were found. The base of the limestone cannot be far below the base of the quarry. The beds dip east, towards the steep left bank of the Lune, approximately 30 yards away, but no limestone is seen in the bank, just shales and sandstones capped by drift. The top of the bank is approximately 5 to 10 feet below the bottom of the quarry. Sections cut from specimens of the limestone (Nos. 26) also reveal the presence of "Algae α", confirming the identity of the limestone as the Great Limestone (see p. 224). This necessitates the continuation of the north west - south east fault from Middleton Bridge, upthrowing the Great Limestone relative to the Laky Hill outlier of Great Limestone to the north.

Beds up to the base of the Low Grit Sill.

The Newbiggin area - Rowantreegill Sike offers the first glimpse of this section of strata. The 8 feet flaggy sandstone previously mentioned (p. 102) probably represents the White Hazle, so that the Little Limestone, although not exposed, should be close by, probably in the 5 feet gap encountered above the sandstone. This gap is succeeded by a 1 feet grey ganister with "cauda galli" markings (No.185). A further gap of 12 feet follows, with one exposure of up to 3 feet of limonite stained, black, fossiliferous shale (with gastropods - No.185) occurring 2 to 3 feet below a 15 feet fine to medium grained, flaggy buff sandstone. This fossil shale may be equivalent to the Faraday House marine band of Stainmore. The first sandstone above the Little Limestone is generally called the Pattinson Sill (Dunham

1948,p.31), and this practice has been adopted here. The Flushie Mine No.2 Mine section shows 2 feet of shale above the Little Limestone, followed by a 1 feet 6 inches girdle bed (called the Pattinson Sill), 36 feet of shale, a 39 feet sandstone (called the Firestone Sill), and 36 feet of shale. Comparison with the stream section suggests that the 15 feet sandstone represents a somewhat attenuated Firestone Sill, with the 1 feet ganister being referable to the 1 feet 6 inches girdle bed, or Pattinson Sill. On the basis of evidence forthcoming in Coldberry Gutter however, this interpretation must be rejected, and the 15 feet sandstone regarded as the Pattinson Sill. It is also suggested that the 39 feet sandstone in the mine section is the Pattinson Sill, and that the 1 feet 6 inches girdle bed corresponds with the 1 feet ganister in the stream section. The sandstone is succeeded by a 6 feet gap followed by some shales and a 2 feet ganister. A further gap of 10 feet is succeeded by 18 feet of shales, and the Knucton Shell Beds, consisting of a lower 4 feet fossil sandstone (with the characteristic <u>Spirifer bisulcatus</u> (J.deC. Sow.)), and a similar, upper 3 feet 6 inches shell bed, separated by up to 15 feet of poorly exposed, soft, friable shale. No sign of the Crag Limestone is seen, and if the 15 feet sandstone were the Firestone Sill, one would expect to see it capping the sandstone. The limestone probably overlies the 2 feet ganister. The Firestone Sill is absent, unless one considers the 2 feet ganister as representing it.

Two features run south from the stream until interrupted by the Flushiemere Great Vein. The lower feature, flanked on the west by drift, carries the Pattinson Sill, while the upper feature contains the two fossil sandstones and runs southwards as a fairly prominent feature for over 800 yards, below and roughly parallel to the 1750 feet contour. North of the stream, the Pattinson Sill feature is overrun by drift, but the Knucton Shell Beds feature swings around to the north west above the drift, running just below the 1750 feet contour around the head of Flushiemere valley. The shell beds are revealed 500 yards south of Rowantreegill Sike in a small east - west stream (which is unmarked on the 6 inch O.S. map) which cuts the feature. Immediately north of the Flushiemere Great Vein, loose blocks of fossil sandstone indicate the proximity of the shell beds (or possibly the lower one only). Above the shell beds in Rowantree-gill Sike, nothing is seen below the Low Grit Sill, apart from an exposure of some fine to medium grained sandstone.

In Bleagill Sike to the south, the beds are once more exposed. Immediately north of the Flushiemere Great Vein where it crosses the stream, an 18 inches fossil sandstone overlies 15 feet of black, limonite-stained shales. It is not clear which of the shell beds this is. Approximately 230 yards upstream a waterfall shows the following succession below the Low Grit Sill:

	Ft.	-	Ins.
Limonite-stained, friable, grey shale.	4	-	0
Coal.	0	-	4
Black, carbonaceous shale with coal streaks.	0	-	6
Sandy, micaceous shale.	5	-	0
Interbedded coarse grits, fine grained sandstones and sandy, black, micaceous shales, with grits predominant.	11	-	0

In Bleak Ley Green Hush, the Pattinson Sill consists of 25 feet of medium to coarse-grained, largely current-bedded, grit, the lower 4 feet of which is micaceous and contains large plant impressions. Some shale chips also occur in the lower few feet. Below it, a gap of 25 feet occurs above the High Coal Sill, with some poorly fossiliferous shales, comparable to those in Rowantreegill Sike cropping out. To the east, a hush out through the strata from the Tuft to the Pattinson Sill reveals a similar succession, with the fossiliferous shale again exposed (No.335) and with the sill maintaining its thickness and lithological character. A fairly prominent feature runs south eastwards to Red Grooves Hushes, where the Pattinson Sill is once more exposed as at least 20 feet of coarse grit, mineralized in places by the Lodgesike - Manorgill Vein. South of the vein, the Crag Limestone is poorly exposed in the hushes, as a fine grained, grey siliceous limestone 2 feet 6 inches thick overlying up to 20 feet of shales underlain by some thin sandstones and sandy shales, dipping south south west at 20^{o} into a branch of the vein with downthrows 40 feet to the south.

On the western flanks of Hardberry Hill Allotment, some confused features occur between the top of the Great Limestone and the prominent Low Grit Sill feature, the most persistent of which probably represents the Pattinson Sill, running in a convex curve from Red Grooves Hushes to the Miry Lane - Hardberry Hill Vein. The only exposure in this tract is in this feature, with 1 feet of medium grained, flaggy sandstone overlying some sandy shales in a small overgrown quarry (924288). The numerous veins between High Stable Edge (925283) and Revelin Shop complicate the picture, but to the south east, the Pattinson Sill crops out in the stream near Revelin Shop as 8 feet of flaggy, micaceous, medium-grained grit, and is also exposed in an old quarry 100 yards south of Bell House (929272). It forms no prominent feature and is obviously thinning. Nothing further is seen of the Sill, or other members of the sequence below the Low

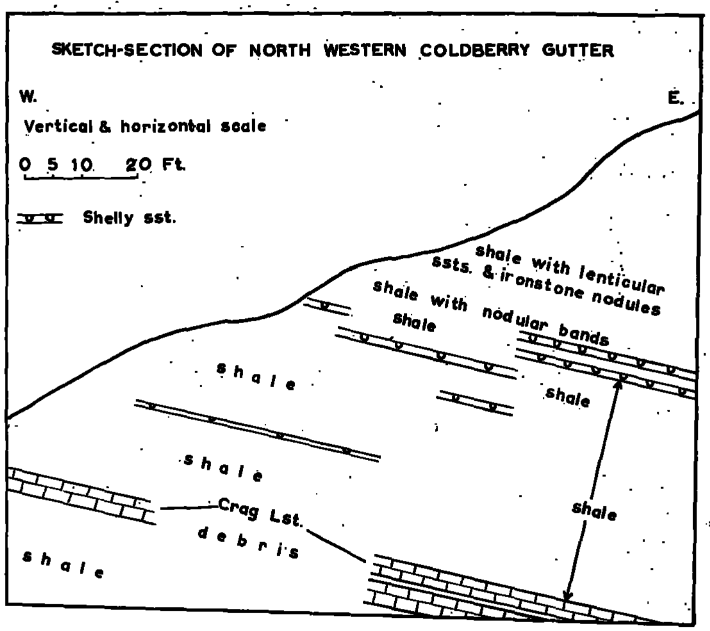
SKETCH-SECTION OF NORTH WESTERN COLDBERRY GUTTER
W.
E.
Vertical & horizontal scale
0 5 10 20 Ft.
Shelly sst.
shale with lenticular ssts. & ironstone nodules
shale with nodular bands
shale
shale
shale
shale
Crag Lst.
debris
shale
shale
shale

Fig. 4

Grit Sill until we reach Hudes Hope, largely because of the thick drift on Tinkler's Allotment.

Coldberry Gutter, Hudes Hope, and Snaisgill Sike - In Coldberry Gutter, north of the Lodgesike - Manorgill Vein, excellent sections of the strata from below the Crag Limestone to the base of the Low Grit Sill are available. At the western end of the Gutter, at least 20 feet of shale are capped by a 3 feet 6 inches limestone, 22 inches of shale, and a 30-inch siliceous limestone, the whole being grouped as the Crag Limestone. This upper limestone post weathers characteristically; the middle portion appears to be less resistant (siliceous) than the upper and lower portions, and weathers out (slightly famped), giving a loose block an anvil-shaped appearance. No Firestone Sill (which Dunham (1948,p.32) states depends for its recognition "upon the presence over a large part of the area of a persistent thin limestone, the Crag Limestone, overlying a coal which rests on top of the Firestone in most sections") is developed here. 32 feet of grey and black shales separate the Crag Limestone from the Knucton Shell Beds, one section of which reveals a 1 feet calcareous fossil sandstone separated from a 15 feet upper fossil sandstone (No.60) by 1 feet 4 inches of soft ganisteroid sandstone. Above these, 59 feet of shale with ironstone nodules and some lenticular sandstones occur, followed by the Low Grit Sill, of which 15 feet to 20 feet of current-bedded coarse grit is exposed. The picture is by no means as simple as that however, as the sketch section (see fig. 4,p. 132) shows. No sign of faulting or folding is seen in this very well exposed section, suggesting that the Shell Beds are not strictly persistent horizons, although some such marine sandstone or sandstones probably occur roughly at this horizon (ie. above the Crag Limestone) throughout the Alston Block, unless removed by the Rogerley Transgression. It might be argued that the two shell beds on the eastern end of the section may be downfaulted to the west, with two of the three shell beds representing the same horizons. The fault could possibly enter the side of the hush at an oblique angle. However each of the three upper shell beds can be seen to give way laterally to shales to the west, so that even if a fault did exist, it would not ease matters. Furthermore if this fault did exist, one would expect to see the Crag Limestone upthrown to the east. It is not. One explanation might be that these fossil sandstones are not the Knucton Shell Beds, but merely some lenticular fossil sandstones at a lower horizon, with the Knuctons removed by the Rogerley Transgression. If this is the case, then the sequence between the Crag Limestone and the Knucton Shell Beds is much thicker than normal here.

At the eastern end of Coldberry Gutter, the Crag Limestone, a fine grained, grey limestone, with some crinoid stems (No.65) directly overlies at least 7 feet of medium grained, grey, speckled sandstone, which represents the incoming Firestone Sill, hitherto unseen. The base of the sandstone is not seen so that the full thickness here is unknown. Above the limestone, up to 30 feet of limonite-stained, black shale with ironstone nodules, and fossiliferous in the lower few feet (No.64 and 65), are followed by two fossil sandstones, the lower 1 feet thick and separated from a 2 feet fossil sandstone, by 14 inches of shale. These shell beds, and those to the west, contain abundant fossils of Spirifer bisulcatus (J. de C.Sowerby) group, which are characteristic of the Knucton Shell Beds. A Shell bed is exposed over thick shales in a small hush running into the Gutter to the north. Some shales and sandstones are seen in Coldberry Grains, but no recognisable horizon crops out. To the south east, in an old quarry 300 yards east of Slate Sill Mine (937289), up to 25 feet of flaggy, grit crop out, coarse at the top but becoming finer grained towards the base. The Crag Limestone is not seen, so it is not clear whether it represents the Firestone Sill, the Pattinson Sill, or part of the both combined. To the south, it forms a feature which runs for a distance of approximately 700 yards before disappearing beneath the thickening drift. Nothing else is seen of these beds on the surface south of Coldberry Gutter, but some useful information is obtainable from the mine records of the area.

At Skears Great Rise, Pattinson's Sill and part of the Firestone Sill are recorded as a composite sandstone of up to 70 feet in thickness, with 10 being assigned to the former (no shale parting is mentioned). From this, it would seem that the 25 feet grit exposed in the quarry mentioned above, represents part of the combined sandstones. The Firestone Sill has thickened rapidly to the south, or south west, from eastern Coldberry Gutter. In Skears Mine Vein F, 500 yards to the south, the Little Limestone is succeeded by 29 feet of shale, a 69 feet sandstone (labelled the Firestone Sill), 5 feet of shale, a 3 feet ironstone, 4 feet shale, and a 3 feet ironstone below 102 feet of boulder clay. It is here suggested that the 69 feet sandstone represents the combined Firestone/Pattinson Sills, and that the ironstones represent the two limestones seen in Coldberry Gutter, assigned to the Crag Limestone. In Vein D, further south, 36 feet of shale separate the Little Limestone from a 69 feet

"Firestone Sill" (?combined Firestone/Pattinson Sills). Above this, 60 feet of shale is followed by a 5 feet sandstone assigned to the Low Slate Sill, but which may represent one of the Knucton Shell Beds. No mention is made of the Crag Limestone. A section for the Lodgesike - Coldberry Mine, the exact position of which is not clear (except that it is somewhere to the north east of Skears Great Rise) records a 68 feet 6 inches Firestone (? Firestone/Pattinson) underlain by 36 feet of shale and the Little Limestone. Above comes 3 feet of coal, till-bed, and shale, followed by a 16 feet Ironstone - surely the Crag Limestone (or limestones). This is followed by 43 feet of shale, the "Low Fiddler Sill" (5 feet sandstone), 24 feet of shale, the "Top Fiddler Sill" (9 feet sandstone), and 12 feet of shale and thin sandstones below the Low Slate (Grit) Sill. These "Fiddler Sills", may represent the Knucton Shell Beds. If they do, they show a very different development to the shell beds seen in Coldberry Gutter.

The picture we have then, is of a Firestone Sill coming in to the east of the Newbiggin area, attaining a fairly considerable thickness rapidly, and coalescing with the Pattinson Sill. The trend of this "washout" seems to follow a roughly north - south direction, or possibly a north north east - south south west direction. A similar washout, following a similar path was seen in the Coal Sills, a significant fact which will be discussed later (see Chap.6).

North of Coldberry Gutter, a 4 feet thick fossil sandstone, with some shales, outcrops in Coving Sike. Nothing further is seen through the drift blanket until we reach Hudeshope Beck, near the first fork in the beck (938316). Here, at stream level, a 2 feet 3 inches siliceous limestone (No.172), the Crag Limestone, is seen, displaying the characteristic weathering described in Coldberry Gutter. Some 20 feet to 30 feet above this, a 3 feet calcareous, fossil sandstone is exposed in the right bank, while some shales and sandstones outcrop above the Little Limestone. No significant sandstone development is exposed, and one is led to assume that neither the Firestone Sill nor the Pattinson Sill are well developed here. In the eastern branch of the beck, 230 yards from the fork, the Low Grit Sill caps 21 feet of soft grey shale, over a 5 inches coal, 5 inches of sandy shale, and a thin sandstone. This coal is presumably the same one as that met with in Bleagill Sike (p. 130).

Down the eastern side of Hudes Hope nothing is seen until a stream exposure (940306) of one of the Knucton Shell Beds, 3 feet 6 inches thick, just above the 1500 feet contour. Some fine grained sandstones and shales are exposed above. At approximately the same height, a fossil sandstone, varying from 2 feet to 4 feet in thickness crops out at the head of both branches of Racketgill Sike, and a hush joining the southern branch. Below, shales and sandstones occur, but in none of these localities is the Crag Limestone seen. Further to the south east, in Longmire's Gutter, two shell beds, a lower 1 foot bed, and an upper 4 feet bed (No.70) are exposed, one on the 1500 feet contour, the other a short distance below. 130 yards down the level from the latter, some fossil shales (No.69) are seen which may be equivalent to those above the Crag Limestone in Coldberry Gutter, but again the limestone itself is not exposed. ? Crag Lime

In Lodgesike Low Level at 1381 feet O.D., the Knucton Shell Bed is met with 660 feet from the portal on the downthrow ? Probably (southern)side of the Lodgesike Manorgill Vein, opposite one of the Grit Sills (Dunham, 1948,p.301). The level of the Knucton Shell Bed must therefore be somewhere between 1300 feet and 1400 feet O.D. The first outcrop of the Knucton Shell Beds south of the vein is north of Marlbeck Gutter, on the 1250 feet contour. A north west - south east fault, down south west, has been mapped between these two points, running just east of Cat Level (954287), and south eastwards as far as Eggleston Burn. Though complicated by an east north east - west south west vein and a north west - south east vein, the following succession can be made out in the complex of hushes north of Marlbeck Gutter:

		Ft. - Ins.
Fossil sandstone.		2 - 6
Gap, probably all shale.	20 ft. to	25 - 0
Shaly, muddy, fossil limestone (lime-plate).	4 ft. to	5 - 0
Gap.		10 - 0
Buff limestone (Crag Limestone) (Nos. 66 and 67).		3 - 0
Grey-buff ganister.		6 - 0
Shale.		12 - 0
Grey ganistroid sandstone.		6 - 0
Coal.		0 - 2
Ganistroid sandstone.		8 - 0
Gap.	3 ft. or	4 - 0
Fine grained grey sandstone (poorly fossiliferous).		6 - 0
Gap.	30 ft. to	40 - 0
Great Limestone.		

The Firestone Sill here seems to have dwindled to 6 feet of ganistroid sandstone, a drastic reduction compared to the thickness recorded in the mines to the west. The identity of the lower sandstones is not clear because of the non-exposure of the Little Limestone. The 6 feet poorly fossiliferous sandstone might possibly represent the White Hazle, but this is somewhat conjectural. If this be so then the Pattinson Sill may be represented by 14 feet of ganistroid sandstone with a 2 inches coal 6 feet from the top (if the Little Limestone occurs in the intervening gap). In the circumstances it seems best not to designate any of the lower sandstones to any particular horizon. The identity of the Crag Limestone seems certain, in view of the presence of a fossil sandstone some 35 feet to 40 feet above.

Hulergill Sike, to the south, reveals a shell bed immediately east and west of the road, but no other recognisable horizon is met until the Great Limestone below, and the Low Grit Sill above. Apart from some poor exposures of the Crag Limestone in Skears Hushes, nothing of further use is seen to the south in the numerous, largely overgrown, hushes, until the hush along Skears Old Vein which downthrows approximately 10 feet - 15 feet south. Here the Crag Limestone is revealed as 3 feet of dark grey lime-stone, sandy towards the base, overlying a 2 inches fireclay, and 4 feet 3 inches of flaggy and shaly micaceous sandstone. Below this, nothing is seen until a 10 feet sandstone regarded as the White Hazle, 50 feet below. The thin sandstone below the Crag Limestone must be regarded as the Firestone Sill, still in a very much attenuated state - any significant sandstone development below this would be expected to reveal itself in the steep sided hushes at some point. No coal is developed above the fireclay.

An exposure of one of the Knucton Shell Beds 100 yards south of Gate Castles Quarry (952274) gives us our only glimpse of the beds between the Great Limestone and the Low Grit Sill from Skears Old Vein to Snaisgill, 2/3 mile to the south east. Here, a 2 feet fossil sandstone with 5 inches of tough, dark-grey, fine grained, fossiliferous limestone (No.240) at the base, overlies a ganister. Above are some black shales with ironstone nodules.

The Crag Limestone in Snaisgill Sike comprises 5 feet 4 inches of grey siliceous limestone, slightly fossiliferous and weathering in the same characteristic manner as was observed in Hudeshope Beck and Coldberry Gutter. It overlies some sandy shales above 2 feet of fine - grained, grey, calcareous sandstone. Below this, fossiliferous black shales with ironstone nodules (No.72) are exposed. 80 to 100 yards downstream, near the mouth of a small tributary, 15 feet of shaly sandstone are seen, possibly representing the Pattinson Sill. Carruthers (1938) drew attention to the absence of the Firestone Sill in Snaisgill Sike, equating some thin bedded flags below the Crag Limestone with similar beds in Swinhope. Carruther's Crag Limestone was a mere 9 inches thick however, separated from some 4 or 5 feet of 'lime plate' above, by 8 feet or so of shales. This thin limestone was not seen during the present survey, and may possibly be covered by loose shale material, which abounds in the stream banks. Presumably the 'lime plate' represents the siliceous limestone herein classed as the Crag Limestone though the bed is a perfectly good limestone and not shaly. The Crag Limestone is upfaulted by a small north west - south east fault (up 6 feet north east), being re-exposed 30 yards upstream (956271). A further 100 yards upstream, a 4 feet grey shelly sandstone (No.10) crosses the stream approximately 40 feet above the limestone. Carruthers reports two shell beds in this section, a lower 18 inches and an upper 5 feet 6 inches bed, but repeated searches have failed to reveal the 18 inches bed, the 5 feet 6 inches sandstone presumably being the 4 feet fossil sandstone of the present survey. Between the fossil sandstone and the Low Grit Sill, some 30 feet above, isolated exposures show a 7 feet flaggy, fine-grained, grey sandstone with shale partings, dipping east south east at 7°, and 6 feet of limonite-stained, black shale, dipping in the same direction. In the above mentioned tributary, a 3 feet fossil sandstone crops out immediately south east of the conjectured position of the Holm Head Vein, which downthrows to the south east.

East and west of Snaisgill no recognisable horizon in this section of strata is seen below the Low Grit Sill, some 25 feet of shales and sandstones below the latter in Howgill Sike being all that is exposed, apart from a few feet of sandstone and shale in an old quarry 300 yards east north east of Hunter's Well House (958262).

Eggleston Burn, Great Eggles Hope, and Stobgreen Sike - In Eggleston Burn, 210 yards south of Blackton Bridge, 3 feet of grey, crystalline limestone crop out followed by 9 feet of fine grained, fossiliferous, black shale, and a 2 feet thick, fine grained, grey siliceous limestone. These beds are succeeded in turn by at least 25 feet of fine grained shale (the lower few feet being fossiliferous - No.80), and a 30 inches limonite-stained, grey, calcareous, fossil sandstone (No.81), one of the Knucton Shell Beds. This latter outcrops high up the side of Bell Sike, near its confluence with Eggleston Burn, and can be traced up the right bank of the burn, dipping at up to 10° in a northerly direction, until it crosses the burn 23 yards north of Blackton Bridge. Here, 8 feet of sandy shale, capped by 2 feet of fine grained ganistroid sandstone separate it from the pebbly base of the Low Grit Sill.

The fossil sandstone is one of the Knucton Shell Beds, and the 2 feet limestone is regarded as the upper member of the Crag Limestone, separated from the lower limestone by 9 feet of shale.

The base of the lower limestone is not seen. 200 yards down-stream, an 18 inches micaceous, sandy, famped limestone taken as the Little Limestone (see p. 124) crops out in the right bank, succeeded by grey shale. The intervening ground is unexposed, but were these beds projected upstream they would cross the burn very near the Crag Limestone outcrop, leaving room for only a few feet of intervening beds. While the hazards of such an arguement are realized, consideration of the run of the Grit Sills west of Eggleston Burn (see p. 154) lends some support to the insertion of a north north west - south south east fault down-throwing to the north north east between the two exposures.

Reading (1954, p. 65) examined this section, and, on the basis of lithological comparison, identified the Knucton Shell Bed as the Faraday House Marine Band, the overlying grit as the Firestone Sill, and the limestone "40 feet below" the shell bed (and therefore probably the lower limestone herein thought to be part of the Crag Limestone) as the Little Limestone. The twin nature of the limestone, the characteristic lithology and fauna of the shell bed, and the prominent grit developments above, leave little doubt concerning the identification of the beds as the Crag Limestone, the Knucton Shell Bed, and the Grit Sills respectively. The Firestone Sill is absent to the west in Howgill Sike and Snaisgill Sike and to the east in Stobgreen Sike while no comparable shell bed referable to the Faraday House Marine Band has been located in the area mapped. If the presence of a north north west - south south east fault be denied, one is left with one of two alternatives. Firstly, one could invoke a drastically reduced sequence between the Crag and Little Limestones, but this would not be justified by considerations of successions to east and west. In Stobgreen Sike to the east, for example, 60 feet of shales, with no sandstone developments, separate the two limestones. No such thickness can occur in Eggleston Burn. Secondly, the limestone identified as the Great Limestone downstream (see p. 123) might conceivably be a thick development of the Little Limestone (10 - 15 feet), but the coral band and the lithology of the limestone argue against this. Faulting does seem the simplest and most likely solution.

Northwards from Blackton Bridge, Eggleston Burn and Great Eggles Hope are flanked by the fault-repeated Grit Sills for a distance of 3 miles, up to Flake Brig Vein. Thence, for at least 300 yards upstream from Wiregill Lead Mine (976302), up to 13 feet of coarse-grained current-bedded grit crops out, identified by Carruthers as the Firestone Sill, though the Crag Limestone is not seen. 300 yards upstream from the Manorgill Sike confluence, a 1 feet 9 inches fossil sandstone is exposed at stream level, but none of the associated strata are seen, apart from the Low Grit Sill. Approximately 400 yards further upstream, an east north east - west south west vein, which has been worked from two levels in the left bank, throws up to the north, exposing, in the right bank, two shell beds, an upper 6 feet and a lower 1 feet 9 inches, with 16 feet of intervening shale. The shale is poorly fossiliferous and contains ironstone nodules. Below, a few feet of shale occur. 230 yards to the north west, again in the right bank, an almost identical section is seen, except that the underlying shales yield some fossils. The upper fossil sandstone, together with approximately 12 feet of the underlying shale, is again exposed 100 yards upstream in the left bank, for a distance of 90 yards, where it is interrupted by a small east north east - west south west fault, down 1 feet north. Immediately north of the fault, in the right bank, the 6 feet shell bed (No.121) dips at 10° into the fault. A second, parallel fault crosses the stream 40 yards to the north, downthrowing 6 feet to the north, and bringing the top of the upper Knucton Shell Bed down into the stream bed.

A section from the middle level to the low level at Manorgill Mine, shows below the Low Grit Sill 10 feet of shale and a 5 inch coal above a 58 feet 7 inches sandstone representing the Firestone Sill. Below this, the following succession occurs:-

		Ft.	-	Ins.
Shale.		4	-	4
Girdle bed.	3 ft. to	5	-	0
Shale.		13	-	6
Sandstone.		5	-	0
Shale.		2	-	0

No mention is made of the Crag Limestone or the Knucton Shell Beds, but the position of the middle level in relation to the mapped outcrops north of Manorgill Sike serves to identify the first thick sandstone below the sole of the level as the Low Grit Sill. The Pattinson Sill is either represented by the thin, girdle bed, or 5 feet sandstone, or combines with the Firestone Sill to form the 58 feet 7 inches sandstone. The latter seems probable. The Firestone and Pattinson are but poorly developed on the east of Hudes Hope, but here, we have a thick sandstone development comparable to that west of Hudes Hope. The Knucton Shell Beds are unrecorded and may have been removed by the Rogerley Transgression.

In Stobgreen Sike, 170 yards upstream from the road at Town Head, 60 feet above the Little Limestone, the Crag Limestone outcrops as 6 feet of dark grey, fine grained, siliceous limestone

(No. 264). The intervening strata consists of black, fine grained shales, totalling approximately 60 feet (but with some gaps up to 10 feet) with a 1 feet thick calcareous mudstone situated 20 feet below the Crag Limestone (see fig. 3c, p. 74). Above the Crag Limestone, nothing is seen through the drift cover until the Grit Sills outcrop, 130 yards upstream. No sandstone development is seen, and in all probability doesn't occur, between the Little and Crag Limestones. This adds some weight to the supposition of a condensed sequence in Eggleston Burn, but the intervening shales are much thicker in Stobgreen Sike.

<u>Lunedale</u> - The best available section in the part of Lunedale mapped occurs in Shields Beck (see fig. 3c , p. 74). A gap of 10 feet or so occurs above the Little Limestone, and then a thin tough grey ganister is seen above some silty shales. A further gap of approximately 15 feet is followed by some sandy shales and sandstones grading up into black shales which are capped by a 4 feet sandstone with a shelly top. A few yards upstream the Crag Limestone outcrops as 5 feet of grey crinoidal limestone (No.317) capped by 8 feet to 10 feet of fossiliferous, calcareous shale, and a 4 feet muddy limestone. These beds dip south south west at 13°. 70 yards further upstream, the Knucton Shell Beds are represented by a 4 feet limonite-stained, calcareous, fossiliferous, fine grained sandstone (No.316) with 7 inches of fine grained, grey, limonite-stained limestone at the base. Below, 8 feet of fine grained black shales with ironstone nodules occur. No Firestone Sill is developed. The 4 feet fossil sandstone some distance below the Crag Limestone can be picked up further west, but its identity is not known, though

Dunham (1948,p.32) mentions that the White Sill (or High Pattinson) of Alston Moor is overlain by a shelly sandstone or marine shale. It would be unwise to suggest correlation of these two horizons over such a distance however, especially in view of the fact that no comparable horizon has been met with elsewhere in the area mapped.

To the west, the shelly sandstone is seen in a small stream running down from Swarthy Mere (961226), where a 16 inches fossil sandstone (No.315) overlies a 2 feet ganister which grades down into a ganistroid sandstone. It occurs just below the 1075 feet contour as compared with a height of approximately 960 feet in Shields Beck. The dips in this area are southerly, the difference in level being accounted for by a north west - south east fault downthrowing to the north east (see p. 126). To the west, the ganister has been worked in some shallow quarries on or near the 1075 feet contour. Further west, it is again exposed in two localities, south and south east of the easternmost West Pasture Road Quarries (955226 and 957226), as 3 feet of micaceous, limonite-stained, ganistroid sandstone, being slightly downthrown to the west by a north - south fault (see p. 126).

In the Swarthy Mere stream, three poor outcrops of muddy crinoidal limestone (at different levels) represent the Crag Limestone or limestones. Some shales and mudstones are exposed in Easter Beck over half a mile to the west, but their horizon is uncertain.

The Lunedale succession is notably lacking in any significant sandstone development, and marine conditions seem to have been more prevalent as indicated by the fossil sandstone and fossil shales, apart from the expected Crag Limestones and Knucton Shell beds.

The Grit Sills and beds to the base of the Transgression Beds Grit; the Rogerley Transgression.

The Newbiggin - Hudes Hope area. - The Low Grit Sill forms a prominent feature on Newbiggin Common, on the eastern slopes above Flushiemere, gradually descending to the south from approximately 1850 feet O.D. at the head of Rowantreegill Sike, to 1750 feet O.D. before swinging around to the south east to cross Bleagill Sike just below 1750 feet O.D. From Bleagill it runs south for 400 yards and is then interrupted by the Flushiemere Great Vein. In the sike, 15 feet to 20 feet of the Low Grit Sill is revealed, a coarse-grained, current bedded (with a northerly source), grit (No.188) becoming finer grained towards the base. Above the grit, 10 feet to 15 feet of sandy, micaceous grey shale outcrop in the stream, followed, 40 yards upstream, by 10 feet of sandy shale and shaly sandstones with a capping of 10 feet of fine-grained, flaggy, micaceous, buff sandstone. Above, nothing is exposed in the stream until 5 feet of shale immediately below the Transgression Beds Grit. This 10 feet sandstone, the High Grit Sill, forms a weak, but increasingly prominent feature to the south, but to the north, a typical concave shale feature separates the Low Grit Sill and Transgression Beds Grit, and below Carr Crags, 20 feet to 25 feet of shale, but no sandstone, outcrop in a small stream (unmapped on 6 inch O.S. map). The High Grit Sill does not die out to the north, but rather to the north west, or west, as is brought out by evidence in Hudes Hope and Coldberry Gutter.

On Lord's Allotment the Flushiemere Vein (no longer mineralized)swings to an east south easterly direction (finally dying out in Coldberry Grains) bringing up the Low Grit Sill on the south, to form the flat-topped, peat covered, feature of Coldberry Moss, with the grit itself dipping to the east. It outcrops along the top of the northern slopes of Coldberry Gutter as 15 feet to 20 feet of coarse grained, massive, current-bedded grit. To the north, on the eastern side of Coldberry Moss, the grit feature is hardly affected by the above mentioned fault, testifying to the fact that it is dying out.

On the southern side of Coldberry Gutter, the downthrown Low Grit Sill (S. 100 feet+) has been quarried south of Red Grooves Hushes (927288). Here, 20 feet of coarse grained, current bedded (no fixed direction) grit is exposed (No.58). It can be traced into Coldberry Gutter, dipping fairly steeply at 10° to 15° in an east north east direction. To the south, it forms a curved feature until interrupted by the north east - south west Hardberry Hill - Miry Lane Fault. Beyond this, drift obscures any feature the grit may form.

Close above, a second, less prominent feature is formed by the High Grit Sill, with some fine-grained, flaggy, micaceous sandstone exposed in an old Clay pit (928286). This feature is thrown up to the south by the Hardberry Hill - Miry Lane Fault, but can be readily traced, above the drift, around Hardberry Allotment, with a further interruption caused by the Lead "C" - Old Ravelin Vein, downthrowing to the south. A further exposure of fine grained flaggy sandstone is seen in some old quarries in the feature, situated 500 yards west north west of Howgill House (934279). The feature finally peters out near the north east - south west Hunt's Coldberry Vein (down 40 feet north east - Dunham, 1948, p.302), approximately 300 yards south east of the Slate Sill Lead Mine.

Coldberry Gutter offers an interesting section of the grit. At the eastern end, at least 25 feet of current-bedded, medium grained grit crops out, dipping east south east at 20° from the Lodgesike - Manorgill Vein. Traced westwards, the grit is seen to thin and give way largely to sandy shales, so that, at the western end of the gutter, but 15 feet or less, of shale and fine grained sandstone occurs, over 40 feet of sandy shales with thin, shaly, fine grained sandstone, dipping south and south east at 10° to 20°. This westerly attenuation tallies with that seen further north below James's Hill. Above the High Grit Sill in the western end of the gutter, after 9 feet of shale, a 4 inches limestone occurs (possibly the Lower Felltop Limestone or the Rookhope Shell Beds) capped by 10 feet of shale. A mine record for Lodgesike - Coldberry (where exactly the section occurs is not clear) reports the Low Grit Sill as being 52 feet thick, capped by 45 feet of shale, an 8 feet sandstone, and 16 feet of shale.

North of Coldberry Gutter, on the western flanks of Hudes Hope, good features enable one to trace both grits accurately for nearly 1½ miles to the head of Hudes Hope, where the various streams of Hudeshope Grains afford useful sections. The Low Grit Sill is here seen to amount to approximately 75 feet of coarse to medium grained, current-bedded grit (No. 177), with a dip of 7° to the south east recorded in one place (938317). Approximately 10 feet to 15 feet of poorly exposed sandy shales separate this from the High Grit Sill, which is revealed as up to 40 feet of flaggy and shaly, medium grained, micaceous sandstone in a waterfall in one of the streams (936318). In the stream below a level driven at 1856 feet O.D. to work Hudeshope Head Vein

(937321), a few inches of medium grained grey limestone crops out approximately 30 feet below the Transgression Beds Grit. The limestone is possibly the Lower Felltop Limestone. Between these two horizons, exposure is very poor, largely because of mine debris, but probably consists of shales. The limestone is further exposed 160 yards to the east north east, in the fork of another branch of the Grains (938321), where 6 inches or so of fine grained crinoidal limestone (No.178) outcrop in the stream bed. Some fine grained, micaceous sandstone overlying shales, are exposed 60 yards downstream from the latter exposure.

After a gap of 130 to 170 yards beyond the main easterly branch of Hudeshope Beck, the features of both the Low Grit and High Grit Sills can be mapped in a general south south east direction for well over 1½ miles along the eastern slopes of Hudes Hope, the former dying out at Longmire's Gutter (where it is not exposed), the latter 500 yards short of the Lodgesike - Manorgill Vein. No in situ exposures occur along these features.

South of the vein, the Low Grit Sill feature can first be picked up in Marl Beck, on the 1500 feet contour, whence it runs south to just beyond Marlbeck Gutter where the combined efforts of a north east - south west fault (down south) and a north west - south east (down to south west) throw it down to 1350 feet O.D. The effect of the Lodgesike Manorgill Vein is lessened east of Lodgesike by the throw of these faults, which uplift the block of country between them, so that whereas the Low Grit Sill is slightly downthrown to the south, the Transgression Beds Grit is upthrown south of the vein (the throw changing to the east).

In Marl Beck, 20 feet of fine to medium grained buff sandstone is exposed (probably by no means the full thickness when compared with the 52 feet recorded at Coldberry Lodgesike), followed by some soft grey shales. At the head of the beck the slightly sinuous High Grit Sill feature (modified by a patch of drift) can also be traced southwards as far as the north east - south west fault, beyond which the widening drift patch obscures all the solid geology below the First Millstone Grit. Above the High Grit Sill, nothing is seen apart from some sandy micaceous shales, some fine grained olive coloured sandstone with plants, and a thin limonite stained, dark grey, micaceous fossil sandstone (No.113), all of which are poorly exposed in a strong double feature containing these beds and the overlying Transgression Beds Grit. The fossil sandstone is representative of the Rookhope Shell Beds, hitherto unexposed in the area.

The downthrown Low Grit Sill feature (here probably also containing the High Grit Sill) can be traced southwards from Marlbeck Gutter, 30 yards east of the road. Southwards, it becomes more and more prominent as the Hudes Hope drift blanket drops away below it. The feature descends from approximately 1350 feet O.D. at Marlbeck Gutter, until it reaches the 1250 feet contour at Gate Castles Quarry, whence it swings around into Snaisgill Sike, becoming less prominent. In Hulergill Sike (954286) the Low Grit Sill is exposed as a flaggy, fine grained micaceous sandstone capped by at least 24 feet of black shale (micaceous towards the top), a 2 feet 6 inches fine grained grey sandstone, and grey sandy shale. The High Grit Sill is not exposed. Exposures of both grits occur in the only one of the Skears Hushes to extend east of the road, both being medium grained grits. It is Gate Castles Quarry that affords the best view of the Low Grit Sill, 30 feet of very coarse, current-bedded grit being exposed, but neither the base nor the top is revealed. On Brown Dodd, above the quarry, and 140 yards north east, the High Grit Sill first forms an independent feature south of Marlbeck Gutter, with some flaggy, fine to medium grained sandstones exposed in old overgrown quarries (953277). Both features can be traced around Brown Dodd until lost beneath a tongue of drift extending from Hudes Hope up to the head of Snaisgill Sike. This drift, together with mine debris, also obscures the sequence in Snaisgill Sike, apart from a few feet of coarse buff grit referable to the Low Grit Sill. On the eastern slopes of Snaisgill Sike, both features emerge from below the drift, running southwards and then swinging around to the south east until interrupted by the north west - south east fault running up from Intake Sike. The Low Grit Sill is revealed in many old quarries (dipping east at 20° in one (960262)), and in Howgill Sike totals 35 to 40 feet of coarse, current bedded grit. The direction of current bedding is fairly constant here, and indicates a north westerly to west north westerly source. The High Grit Sill is but poorly exposed, some fine grained buff sandstone in the upper reaches of Howgill Sike (966265), 70 yards south of the conjectured position of the fault, being all that is seen.

Some doubts may arise as to the justification of continuing the Intake Sike Fault thus far. The features of both grits die out hereabouts but this, it could be argued, may be due to the drift cover which extends over Stotley Carrs. Also, some old quarries at Stotley Grange reveal a flaggy sandstone which could readily be linked with the High Grit Sill to the west. However, the latter, in Eggleston Burn to the east, occurs at a height 350 feet below the final exposure west of Stotley Grange. This could, of course, be due to normal dips; but the strong Transgression Beds Grit feature above, maintains a relatively constant height above the 1250 feet contour around Raven Hills. The quarries east of Stotley Grange are regarded, herein, as being in a third, higher sandstone, which comes in at about this point, becoming prominent to the north east in Great Eggles Hope. This latter sandstone is not present in the ground hitherto considered, and it may seem convenient that the lines of the supposed fault and the incoming sandstone almost coincide. It is the only feasible explanation of the facts, however, and strata under stress would tend to fracture along such a line, where a sandstone comes in, in place of shales. The combined effects of this fault, and the dip of the beds below the incoming and thickening sandstone would account for the disparity in height between the relative beds in the Stotley area and in Eggleston Burn.

? Not mapped

North of the fault, in Howgill Sike, some thin sandstones and shales outcrop sporadically, below the Transgression Beds Grit.

Foggerthwaite, Eggleston Burn, Great Eggles Hope. - East of Intake Sike, at Whistle Crag, 10 feet of current-bedded (varying directions), coarse, pebbly grit, (No.91) part of the High Grit Sill, was mapped by the Primary Survey as the Firestone Sill. A feature running over Foggerthwaite for 600 yards to the farm south east of Foggerthwaite House (979250), represents the High Grit Sill. Beyond this, the feature is lost beneath drift, but obviously links up with some grit exposed in Bell Sike. Numerous quarries have been worked in this grit on Foggerthwaite, but unfortunately are largely overgrown with but poor grit exposures in some of them. In Bell Sike, however, an estimated total of 25 feet of coarse, current-bedded (north westerly source) grit crops out in isolated exposures. 36 yards downstream from the point where the 900 feet contour crosses the stream, a few inches of silty grey shale outcrops, placing the base of the grit at about 900 feet O.D.

Below Whistle Crag, a feature, littered with very large blocks of course grit, is taken as representing the Low Grit Sill. 160 yards to the south east, this feature can again be picked up through the drift, with scattered in situ outcrops of coarse grit, and traced to Foggerthwaite Quarry (976248), where a member of the Cleveland Dyke system was worked. Up to 17 feet of seemingly massive, medium grained, creamy-grey grit is exposed in the quarry. West of the road, the grit is upfaulted a matter of 10 feet or so to the south, with 15 feet of baked shales containing ironstone nodules exposed below the grit. The fault runs east - west and peters out before reaching Eggleston Burn. South of the fault, the upthrown grit outcrops sporadically along the roadside, and, 200 yards to the south east, has been quarried. It is a coarse grained cream grit and the current bedding indicates a north westerly source. Drift conceals the solid geology to the east, but from below the first house on the road to Bell Sike, a rather weak feature can be followed to Bell Sike where 30 feet of coarse grit outcrops in the stream. The feature is probably weak because of an apron of drift obscuring the lower part of the feature. Eastwards from Bell Sike, no feature or outcrops through the drift, enables one to accurately link the Bell Sike and Eggleston Burn exposures. The grits have obviously come down somewhat steeply between these two streams, and north of Blackton Bridge, dips of 10° north, 13° north north east, and 7° east north east are recorded as one progresses upstream. A measure of the descent is afforded by comparison of the position of the base of the High Grit Sill, being at 900 feet O.D. in Bell Sike, and outcropping below 800 feet O.D. in Eggleston Burn. A north north west - south south east fault has been inserted between these two exposures because, although the dip may possibly account for the disparity in height, such a fault would also help to explain certain problems concerning the underlying succession in Eggleston Burn to the south (see p. 141).

The High Grit Sill is well exposed in a cliff face stretching upstream in the right bank for over 300 yards before the base crosses the stream over 500 yards upstream from Blackton Bridge. Thence it forms the floor of the stream until upthrown by an east north east fault (marked by a Whin dyke - see plate 17A , p. 373), running through Knotts (993262), though exposure is very poor because of drift. On the left bank, an old Cleveland Dyke quarry (see plate 17B , p. 373), and exposures in the bank to the south, reveal the strata intervening between the two grits. In the former, beneath 20 feet of coarse grit, we see 5 feet 6 inches of baked white shale, and a 9 feet recrystallized, fine grained buff sandstone over more baked shale, with a gap of approximately 10 feet above the Low Grit Sill. In the latter exposures, a 7 feet fine grained ganistroid sandstone followed by 3 feet of alternating thin coals and carbonaceous shales with plants, a 16 inches ganister and some shales and coals occur, but neither the top of the Low Grit Sill, nor the base of the High Grit Sills are seen. A similar succession to this is seen in the left bank of the burn, at stream level, 260 yards north of the quarry, dipping east north east at 7°.

When traced around into Blackton Beck, an estimated total of at least 80 feet of coarse to medium grained grit is exposed. Two sets of cliffs occur in the stream, the lower revealing 25 feet of grit (No.269), and the upper 30 feet of coarse grained Grit dipping north east at 6°. The fact that two cliffs occur suggests intervening shales, but any that do occur, and none are seen, cannot total more than a few inches. 130 yards below the final (uppermost) grit exposure in the stream (996251), near the Blackton Smelting Mill, the grit contains coal streaks and plant remains. Above the smelting mill, thick boulder clay obscures all the solid geology. The two grits have evidently coalesced east of Eggleston Burn, to form one thick grit.

South of Blackton Beck, the grits (or grit) form a strong feature running through Mickleside Plantation where some coarse grit outcrops along the road. To the south east the feature becomes less and less prominent until it dies out approximately 300 yards north west of the Northern Eggleston Fault. Some sandstone is revealed in a small stream near Holy Trinity Church (998237), but drift obscures other members of the succession. The dying out of the feature could be attributed to the effect of the fault, even though it downthrows to the north west, and normally one would expect beds to dip away on the downthrow side. One frequently finds the opposite to be true in this area, however, as at Mirk Holm in Bow Lee Beck, and in the small faults seen in the Knucton Shell Beds in Great Eggles Hope. But when examining the section in Stobgreen Sike to the east, the upthrown

Grit Sills (or Sill) are seen to be represented by:

	Ft.	-	Ins.
Coarse grit (No.280).	4	-	0
Shaly buff sandstone.	0	-	4
Fine grained, slightly micaceous, grey-buff, well bedded sandstone.	14	-	0

Above (see fig. 3c ,p. 74) come some ganisters (which may be included in the Grit Sills), coaly shales, and chert and limestones (No. 281 and 282) belonging to the Rookhope Shell Beds. Below, nothing is seen through the drift until the Crag Limestone, 100 yards downstream. Unless the succeeding ganisters (possibly totalling up to 24 feet, including gaps) are included, the Grit Sills are represented by no more than 20 feet of sandstone and grit, so it appears that the dying out of the feature is due largely to attenuation.

The various gaps in the succession above the 4 feet grit suggest shaly members of the succession, and even if the ganisters are included with the lower, thicker sandstone grit bed to form the Grit Sills (making a total of approximately 42 feet), such shale intercalations would show the tendancy of the grits to attenuate in this direction. The topmost ganister exposure is capped by a 1 inch coal smut, 10 inches of chert (No.281), 12 inches to 18 inches of silty, limonite-stained, grey shales, and a 2 feet 3 inches dark-grey, siliceous, limestone (No.281). Upstream, about 5 feet to 6 feet above the limestone, 1 foot of dark, grey, siliceous, shaly mudstone crops out, dipping east at 3^{o} to 4^{o}, but changing rapidly to a horizontal position upstream. After a gap of approximately 18 feet, a 4 feet medium grained, buff sandstone, overlies some sandy grey shales, dipping at 7^{o} to the west south west into a west north west - east south east branch of the Northern Eggleston Fault, which downthrows to the south east approximately 20 feet. North of the fault, the following succession is revealed below the Transgression Beds Grit:

	Ft.	-	Ins.
Soft, black, slightly micaceous shale, becoming silty downwards. 12 ft. to	13	-	0
Muddy chert.	3	-	0
Siliceous limestone, less siliceous near the top. (No.282).	2	-	6
Black, siliceous shale.	0	-	6
Ganister.	4	-	0

These beds dip at 30° to 35° to west south west into the fault. The succession is somewhat different, black, siliceous shale taking the place of the coal smut downstream, and with 3 feet of muddy chert appearing directly above the limestone, while the 10 inches chert and overlying shales are absent. Of course, the limestones may not be the same, but this appears unlikely. The cherts are the first met with in this area, and point to local depositional conditions which were different to those prevailing in the area to the north generally.

In the River Tees, below Eggleston Bridge, between Black Sills (002226), and Tophet Hole (003224), a massive, medium grained, slightly micaceous, quartzitic sandstone, 5 feet of which is exposed, capped by a 5 feet ganister, probably represents part of the Grit Sills. At Black Sills, a north north west - south south east fault crosses the Tees, throwing up the sandstone to the east. On the downthrow side, a 5 feet 3 inches dark grey, tough shaly slightly micaceous, siltstone crops out (No.276), capped by 1 foot of silty, limonite-stained, black shale, 1 foot of tough ganister (No.276), and finely laminated, soft, fine grained, black, limonite stained shale. The beds are horizontal, but dip at 3° to the east off the fault. East of the fault the beds dip at 15° to east south east, with a north north east - south south west anticline outcropping in the river bed a few yards to the east. Dips off this fold are 20° on both flanks. Thence downstream, the dip remains fairly constant at between 3° and 5° to south south east. Between Black Sills and Tophet Hole, the Grit Sills are followed by:

	Ft.	-	Ins.
Dark grey silty shale.			
Tough, grey, fine grained, siliceous mudstone. 6 inches to	0	-	9
Limonite stained, dark grey, silty, shale.	2	-	0
Dark grey, shaly fossiliferous siltstone. (No.249).	1	-	0
Fine grained silty grey shale.	0	-	6
Chert. (No.248).	1	-	0
Ganister and Grit Sills.(No.247).			

The succession is laterally variable, but the above is representative. Downstream, opposite Skirtle Bank, the following section is seen in the left bank of the Tees, below the Transgression Beds Grit:

		Ft.	-	Ins.
Friable grey shale, passing down into		8	-	0
Blocky, calcareous, fossiliferous grey shale. (No.260).		3	-	6
Dark grey limestone.(No.260a)	))	2	-	6
Shale parting.	))	0	-	1
Coarse, shelly grey limestone with detrital quartz, quartzite, chalcedony, microcline, and glauconite. (No.260b).	)) Lower			
Black, carbonaceous, blocky shale.	)Felltop	10	-	0
Fine grained, grey, muddy limestone.	))Limestone.	1	-	0
Grey shale.	))	0	-	1
Muddy limestone.	))	0	-	6
Grey shale.	))	0	-	2
Coarse, sandy limestone.(No.260c).	))	2	-	0
Alternating sandy grey shales and sandstones.		7	-	0

Thin limestones with some thin ganister outcrop below the Transgression Beds Grit upstream in the left bank, and undoubtedly belong to the same group, representing the lower limestones, the upper members being progressively cut out upstream by the Coalcleugh Transgression. There are two limestones with shale partings strictly speaking, and H.G. Reading (1954,pp.83-4) states that in the Stainmore-Cotherstone Syncline area, the horizon (the Lower Felltop Limestone) is very constant generally consisting of 2 limestone, of 1-2 feet in thickness separated by 4-8 feet of shales normally, but by a greater thickness in the Tees. Correlation of the Tees and Stobgreen Sike successions in detail is difficult because of the variable nature of the chert-limestone mudstone Rookhope Shell Beds. The chert-limestone beds of Stobgreen Sike can be confidently correlated with the chert-mudstone-siltstone succession seen between Black Sills and Tophet Hole however. In Stobgreen Sike the Rookhope Shell Beds are succeeded by approximately 15 feet of shales; in the Tees, up to 40 feet of strata separate the Rookhope Shell Beds and Lower Felltop Limestone, so that in addition to the Lower Felltop Limestone, approximately 25 feet of beds have been removed by the Coalcleugh Transgression in Stobgreen Sike.

In Eggleston Burn, north of the east north east fault running through Knotts (which may be called the Knotts Fault for convenience) the upthrown Low Grit Sill on the north, crops out as a coarse grained grit, and sporadic grit outcrops enable one to trace it to East Skears Foot (987263), above which, incised meanders cut down through the Grit Sills, and wind upstream for 1,100 yards to East Skears (see plate 21 ,p. 429). Beyond East Skears it opens out into a broader valley to the north. The almost vertical gorge sides provide good sections, of which the following is representative:

		Ft.	-	Ins.
Current bedded coarse grit.		30	-	0
Soft grey shale.		7	-	0
Coal.		0	-	4
Grey sandstone.		8	-	0
Grey shale.		3	-	0
Grey siltstone.		7	-	0
Coarse grained grit (Low Grit Sill).	50 ft. to	55	-	0

The 4 inches coal is undoubtedly equivalent to the coal horizon occurring near Blackton Bridge.

At East Skears an old quarry on the left bank reveals a good section above the High Grit Sill, 25 feet of which is exposed (No.129). The section is:

		Ft.	-	Ins.
Medium grained flaggy micaceous sandstone.	3 ft. to	4	-	0
Sandy grey shale.		5	-	0
Coal.		0	-	$2\frac{1}{2}$
Ganister.		1	-	4
Sandy shales and shaly sandstones.		5	-	0
Coal.		0	-	4
Grey shale.		1	-	4
Ganister.		1	-	6
Black carbonaceous shale.	3 ft. to	4	-	0

The uppermost sandstone probably represents the part of the Third sandstone in this section of strata, mentioned previously (pp. 151-152). A dip of 8° to the south east has been recorded in the High Grit Sill, 140 yards south of East Skears Quarry, in the left bank. A further 430 yards downstream a dip of 8° east north east occurs immediately north of a west north west - east south east fault downthrowing south and bringing the base of the Low Grit Sill (No.130) 6 feet above stream level on the north, against very course grit of the upper part of the Lower Grit Sill on the south. Jointing has been recorded in three places in the grits and shows dominant directions of north 15 - 20° west, and north 75 - 85° east.

North of East Skears, thick drift blankets all except some medium grained, micaceous buff sandstone with some carbonaceous streaks (No.134) which has been mapped as the top of the High Grit Sill, in Horden Sike. Hopehouse Quarry (988279) and another quarry 130 yards to the north, are now overgrown, but were undoubtedly in the High Grit Sill. The next solid exposures occur in East Rake Hush, a mile to the north west in Great Eggles Hope. East Rake Hush is cut along the north east - south west, East Rake Vein which downthrows 10 feet north west. 20 feet of current bedded, medium grained, micaceous sandstone (Nos. 139 and 140), outcrops in the hush, representing the upper part of the High Grit Sill, the base being concealed beneath the outwash fan of debris from the hush. Above, 10 feet of sandy grey shale occur after a gap, followed by 20 feet of fine grained flaggy grey sandstone (No.141) and some shale exposures below the Transgression Beds Grit, at the head of the hush. Both sandstones are sporadically exposed in a stream to the north but in West Rake Hush, the High Grit Sill is concealed beneath drift, and only part of the higher sandstone is revealed. A useful section of some of the beds succeeding, up to the base of the Transgression Beds Grit, is seen however. After a gap of a few feet above the Third sandstone, some fine grained sandstone is followed by 2 feet of dark grey, famped limestone (the Rookhope Shell Beds) and a 3 feet calcareous sandstone capped by at least 11 feet of fossiliferous shale, (No.152) the lower 3 feet being calcareous. Above the shales, a 4 feet fine grained buff sandstone, and 3 feet of dark grey sandy shales crop out. On the left bank of Great Eggles Hope Beck, 60 yards from the ford (979299), 15 feet to 20 feet of flaggy, medium grained sandstone with small pockets of coal and carbonaceous shale are exposed, belonging to the High Grit Sill. North of East Skears, both the base and top of the High Grit Sill are largely conjectural, but the position of the base is available from the records of East Rake Mine: "An adit level at 1,135 feet O.D., starting from the beck 1,700 feet north of the bridge on the Middleton - Stanhope road, driven 3,425 feet north by west in shale beneath the High Grit Sill "(Dunham, 1948, p.310). Thus, although the base is nowhere seen, it can be confidently drawn in above stream level until we reach the exposure north of the ford in Great Eggleshope Beck. The top is fixed in East Rake Hush, and probably in Horden Sike.

South of Wiregill Lead Mine, the Flake Brig Mine crosses the beck (unexposed) and throws up a grit identified as the Firestone Sill (p. 142) on the north against the High Grit Sill on the south. One small grit exposure is all that is seen of the Low Grit Sill in the right bank north of the vein, but in the opposite bank, and running up into Wire Gill, three features clearly represent the three grits or sandstones. These features are equally prominent on the western side of Wire Gill and continue around into the left bank of Great Eggleshope Beck. Various quarries in Wiregill have been worked in both the Low and High Grit Sills, 29 feet 6 inches of coarse grit being exposed in the former, and 25 feet to 30 feet of very coarse, limonite stained grit in the latter. Current-bedding is evident in both, with a northerly source indicated in the Low Grit Sill. In the High Grit Sill quarry east of Wiregill Shop (977307), the grit dips at 7° to east north east, and is followed by a 2 inches coal, 3 feet of sandy, micaceous shale, and a thin, medium grained, fissile sandstone. The coal is possibly equivalent to the 2½" seam in East Skears Quarry.

Nothing is seen of the beds between the two grits.

The third sandstone is first seen 260 yards north of Wiregill Shop, where 10 feet of fine grained, creamy sandstone overlies 20 feet of shale, in the left bank of the stream. 60 yards upstream, some shales above the sandstone are followed by a 9 inches ganister, 5 feet 3 inches of micaceous grey shale, 3 feet of famped, fossiliferous limestone (The Rookhope Shell Beds) (No.159), 4 feet 6 inches of black shale, and 4 feet 3 inches of grey, fine grained sandstone with carbonaceous streaks (No.158) and shale partings. A few feet above, the Transgression Beds Grit is exposed. From Wire Gill, the three sandstone features run northwards up to Little Eggles Hope Vein.

In Manorgill, 30 feet of coarse, current-bedded grit (No.117), pebbly in parts, is exposed in two old quarries (969304), but mine and hush debris render accurate mapping difficult. The High Grit Sill and overlying sandstone are also poorly exposed in Manorgill, but none of the intervening beds crop out. Both the Lodgesike - Manorgill Vein and Manorgill North Vein (the former combining with a north east - south west fault from Cat Level (see p. 398)to form Flake Brig Vein, a short distance west of Great Eggles Hope) cross the head of Manorgill, and the High Grit Sill and overlying sandstone, are mineralized to a greater or lesser extent. Limonite, quartz veining, traces of galena and zinc blende (black jack), all are seen, (Nos. 104, 108). Dips of 15° to north east and south east occur in one of the hushes (967301), indicating the proximity of the Lodgesike - Manorgill Vein, the throw of which is carried in the southern branch. Further information regarding this section of strata is obtainable from mine records. Thus, from the sole of the Middle Level a section descends through 43 feet of shale before reaching a 61 feet 2 inches sandstone referable to the Low Grit Sill - with the position of the middle level fixed on the map, a check is provided as to the whereabouts of the top of the grit in the gill. A section from the middle level to the high level shows, a 12 feet sandstone followed by 18 feet of shale, a 40 feet 8 inches High Grit Sill, 18 feet 4 inches shale, a 36 feet sandstone and 7 feet of shale. The three sandstones are appreciably thicker than in Wire Gill, to the east, but correspond well with the sandstone grit developments in East Skears to the south east.

In Littlegill Sike to the north of Manorgill, 30 feet of grey flaggy sandstone belonging to the High Grit Sill are exposed, but neither the top nor the base are seen. A feature runs northwards, some 270 yards, to the Little Eggles Hope Vein. A lower feature runs from the Low Grit Sill quarries at Manorgill, up to the fault, immediately south of which some coarse grit is exposed. The vein does not noticeably disturb the grits, in the right bank, but its position is marked well in the left bank by two levels, while the Low Grit Sill is thrown up to the north, from stream level, at least 50 feet, 30 feet of coarse flaggy grit referable to the Low Grit Sill outcropping above a sheepfold (966310). The vein appears to die out rapidly to the west. Beyond this, exposures are poor in both banks until we reach the two small northerly throwing faults mentioned previously (p. 143). The Low Grit Sill is once more brought down to stream level, but the only measurable section is at Black Force (961313) where 10 feet of massive coarse grit (No.119) is seen. This is probably by no means the full thickness. The High Grit Sill is well exposed, forming a cliff section in the right bank for a distance of over 230 yards, between the mouths of Lodgegill Sike and Arngill Sike. Here, up to 25 feet of coarse grit outcrops over 10 feet to 15 feet of black shales with ironstone nodules and a few fossil fragments. This occurrence of marine fossils is the only one recorded at this horizon in the area mapped. Above, over 30 feet of sandy grey shales are seen. 10 yards north of the mouth of Arngill Sike, a north west - south east vein (worked from an old level in the west bank of Great Eggleshope Beck) once more throws up the Low Grit Sill, a coarse grit flooring the stream for approximately 95 yards to the north. The fault is revealed in the right bank, where some soft, white, micaceous sandstone (No.122), the High Grit Sill, is brought up against some sandy, micaceous shales and sandstones above the High Grit Sill, on the south. The vein runs south east to join Little Eggleshope Vein.

Exposures north of the vein are numerous. The High Grit Sill comprises some 20 feet of soft, white, micaceous sandstone, and is separated from the Low Grit Sill by 25 feet of more or less sandy black shale with ironstone nodules. Close above the High Grit Sill an 8 inch coal (comparable to that in Wire Gill), is followed by 15 feet of variable shale and sandstone, dipping north north east at 6^{o}. The succession proves to be highly variable and it is difficult to draw an accurate, comprehensive picture of the section. The third sandstone is represented by 12 feet or more of flaggy, micaceous sandstone, followed upstream by some thin flags and shales below a 2 feet ganister. Above the ganister, 18 feet of poorly fossiliferous, limonite-stained black shales (No.155) are capped by at least 10 feet of shales and sandstones below the Transgression Beds Grit. These fossil shales may be equivalent to those above the limestone in West Rake Hush.

The Grit Sills are seen to thin progressively upstream (i.e. north north west), the Low Grit Sill to no more than 30 feet, and the High Grit Sill to as little as 15 feet to 20 feet, while the intervening shales and sandstones become correspondingly thicker. No sign of the Lower Felltop Limestone is seen in the upper reaches of Great Eggles Hope. The coal above the High Grit Sill is persistent, and has thickened to 8 inches. In the Flushiemere - Hudeshope area to the west, the Grit Sills were seen to thicken to the east or south east. The situation is similar in Great Eggles Hope and Eggleston Burn, but at the head of Hudes Hope the sills are very thick and coarse grained, while at the head of Great Eggles Hope, the High Grit Sill at least, is unusually thin for the valley. Thus we have the picture of the Grit Sills thickening in a belt up to 2 miles. wide running in a north north west - south south east direction. Dunham (1948, p.37) describes a 2½ mile wide "washout" which lies east of the headwaters of Great Eggles Hope, and which is believed to continue southward to Eggleshope Mines from Weardale. The belt of strong sandstone or grit development herein described, runs south eastwards from the Hudeshope Head area to the Blackton Bridge area - that is, west of the headwaters of Great Eggles Hope. Whether the belt described by Dunham does not in fact continue southwards, running east of the headwaters, but swings sharply westward to the head of Hudes Hope, is a possibility, but a remote one. The existence of two such belts is a far more likely explanation.

Lunedale. - In Wester Beck a 6 - 7 feet medium grained sandstone over some shales proves to be the sole possible representative of the Grit Sills. Some distance above, grey shales, capped by a 4 feet grey siltstone which is calcareous at the top, dip due south at 11° below some black micaceous shales with ironstone nodules. Then above these shales we have the following succession:-

		Ft.	Ins.
Muddy limestone (No.322)	Lower Felltop Limestone.	0	7
Fine grained grey limestone.		1	1
Soft grey shale.		0	5
Coarse, greenish - grey limestone (No.322a) passing down into calcareous mudstone.		1	0

H.G. Reading (1954, p. 76) identified these limestones as the Rookhope Marine Band (Lower Stonesdale Limestone) - there were no diagnostic characteristics for these beds in Stainmore (except Westmorland) and Reading recognised them on the basis of "the constant occurrence of a marine band between the Upper Stonesdale Limestone (Lower Felltop Limestone) and the Grit Sills" (p. 74). 100 yards upstream, a thin fossil band in the shale was regarded by Reading as representing the Rookhope Ironstone, which outcrops in 'No Name Beck' to the west, and which, he states, can be traced to Wester Beck by means of a broad shale feature - the shales in which this fossil band occurs. The basal part of the limestone which Reading identifies as the Rookhope Marine Band is glauconitic (No.322a) and lithologically identical with the basal part of the upper post of the Lower Felltop as seen in the Tees, and on this basis has been so identified (see pp. 235-36). The calcareous siltstone below is a finer grained development of the lower post of the limestone, while the fossil shale above can be correlated with the fossil shales above the Lower Felltop Limestone in the Tees. Reading emphasized the constant lithological nature of the Lower Felltop horizon in his area, and also states that the Rookhope Ironstone dies out east of Wester Beck. It may die out east of 'No Name Beck' or may occur below the Lower Felltop in Wester Beck, though not exposed.

To the east, drift conceals the solid geology for over half a mile, until a feature with some shallow, overgrown quarries containing some loose flags of fine to medium grained, micaceous sandstone (No.311), rises through the drift and runs in an east north east direction until interrupted by the West Pasture Road Vein. The combined effects of the vein and the north - south fault to the east, throw up the 'Grit Sills' to the east, above Swarthy Mere. A fairly distinct feature with many shallow overgrown quarries, runs below Green Rigg for 400 yards to Shields Beck, where a few feet of medium - coarse grained, limonite stained, grit outcrop. Some loose grit flags are seen in the quarries, but no in situ exposures; the grit cannot be very thick however, judging from the shallowness of the quarries. To the west the feature runs almost up to the north - south fault, but the quarries end west of Swarthy Mere, and no sandstone is seen in the streams to the west. Although the sandstone has been mapped as a continuous sandstone to Wester Beck, it might in fact be undeveloped between the quarries west of West Pasture Road Vein, and those on Green Rigg, the sandstone in these two areas representing ribbon-developments with a general north - south tread. East of Shields Beck, the feature continues up to the north north west fault running south of Stoophill House (p. 126). Beyond this, the downthrown grit swings around into the more substantial feature of Bail Hill with an exposure of 16 feet of current-bedded, medium-grained buff grit (No.300) in some old quarries, testifying to the easterly thickening of the horizon. The grit here dips due south at 11°, and the current bedding indicates an east north easterly source. A slight fault east of Bail Hill Road lets down the grit to the east, where it is exposed in some small quarries or pits in a plantation. Only 4 feet or so of medium to coarse grained, current bedded grit (No.253) crop out, dipping due south at 20° - the steep dip being no doubt due to the influence of the nearby fault. The next exposure is in the old quarry near Hayberry Well (985227) immediately south of the Teesdale Fault. A dip of 10° to 12° south south west occurs in 34 feet of current bedded, coarse to very coarse grit (No.251). The easterly expansion of the grit is obviously continuing. In the plantation exposure a northerly source is indicated, and in the quarry, a north easterly source for the grit. The top of the grit east of Bail Hill is conjectural until exposures in Thackwood Beck (985223). Here, outcrops in old quarries of up to 30 feet of coarse, current bedded grit (northernly source) occur, with a dip of 10° north north west recorded in one quarry (986223), so that a synclinal fold exists beneath Hayberries Plantation. After crossing the beck, the top of the grit, which has been steadily moving down the contours, swings around the spur into Hole Beck. Grit exposures in the beck and some old quarries allow fairly accurate mapping. 18 feet of coarse grit is exposed in one (986221), while another quarry (986220) reveals the actual top of the grit capped by 7 feet or more of silty black shale. The grit thus exposed in Thackwood Beck and Hole Beck was linked with the

Transgression Beds Grit capping the ground between Hayberries Plantation and Grace's Cottage (982225) by H.G. Reading (1954), but this shale exposure and the synclinal fold below Hayberries Plantation, bringing up the Grit Sills, leads one to suspect this interpretation.

No grit or sandstone developments occur between this and the Transgression Beds Grit above. Whether this grit represents one of the Grit Sills, or a combination of both, dying out to the west, is conjectural. Above the grit, nothing is exposed east of Wester Beck until we reach Shields Beck (or Coal Gill) where we see a 6 inches limestone (No.316) capping a sandstone some distance above the Grit Sill. This was taken by Reading as the Rookhope Marine Band, 60 yards upstream, a 2 feet thick, dark grey, gritty limestone (No.314), overlies some black shales. It represents part of the Lower Felltop limestone, and compares favourably with the basal 2 feet of the lower limestone seen in the Tees opposite Skirtle Bank. Above this, a gap of 8 feet or 9 feet is succeeded by 11 feet of shales and thin sandstones, below the Transgression Beds Grit. No sign is seen of the upper limestone belonging to the Lower Felltop Limestone, the Rookhope Ironstone, as pointed out by Reading (1954,p. 77) has died out in this area. No coal is seen to justify the name of the gill, but an old coal drift on the right bank below Toddyshaw Hill (966225) testifies to its presence. Further east, in Wadycarr Sike, an 18 inches, coarse, calcareous, limonite-stained grey grit (basal portion of Lower Felltop Limestone) overlies some sandy grey shales grading down into a flaggy grey sandstone, some 20 feet below the Transgression Beds Grit. 70 yards downstream some fine grained shaly, grey, calcareous sandstone is exposed possibly representing the Rookhope Marine Band. Old coal drifts near the Tile Works at Wady Carr (979225) signify the continued presence of the coal in workable thickness, but here again it is not exposed. Reading regarded this coal as the Tanhill Coal (p.108).

The Rogerley Transgression - The name was given to the transgression below the Low Grit Sill by Dunham (1948,p.36), as its maximum development in the neighbourhood of Rogerley Intake, 1½ miles east of Stanhope, where it cuts out the Firestone ganister. The existence of the "washout belt" in the Grit Sills to the east of Great Eggles Hope headwaters described by Dunham has already been referred to (p. 166), and on both sides of this belt, which is 2½ miles wide in Weardale, the transgression lifts, to preserve the Knucton Shell Beds. The second belt of thick sandstone development extends in a north north east - south south west direction from Hudeshope Head to Blackton Bridge (p. 166). The Knucton Shell Beds are nowhere seen to be cut out here, except possibly at Blackton Bridge, where but one shell bed occurs, with 8 feet of shale and 2 feet of ganistroid sandstone below the Low Grit Sill. It is of some significance that the Grit Sills coalesce and attain their greatest thickness a short distance to the east of this point. Apparent absence in most localities is probably due to non-exposure, rather than removal. The apparent inconsistency of the Knuckton Shell Beds in Coldberry Gutter may lead one to regard the presence of one shell bed at Blackton Bridge as another local variation, affording no evidence of transgression above. However, the widespread occurrence of two shell beds, not only over this area, but the Northern Pennines as a whole, tends to suggest that the

Coldberry Gutter section is merely a unique local development. The possibility of the Coldberry Gutter fossil sandstones being lenticular bodies not representing the Knucton Shell Beds must not be overlooked. If this be so, the question remains as to where the latter beds are - removal by the Rogerley Transgression is unlikely in view of the relatively poor development of the Grit Sills in that area. The Rogerley Transgression appears, in this area, to be largely ineffective except at Blackton Bridge. In this respect however, the shaft records of Manorgill Mine show no sandstones referable to the Knucton Shell Beds below the Low Grit Sill, which overlies 10 feet of shale, and 5 inches of coal, above the Firestone Sill. Unless, therefore, the mine sections have been wrongly interpretted, the Knucton Shell Beds and the Crag Limestone have been removed by the Rogerley Transgression. To the east, in Great Eggles Hope, the Shell Beds are both preserved, while the Grit Sills are less strongly developed (pp.164-166). The situation is then, that we have a transgression active along two "washout" belts, one of which can be definitely proved (Weardale), and a second which seems highly probable.

The course of the Hudeshope Head - Blackton Bridge "washout" to the south is not clear. In Stobgreen Sike the Grit Sills are comparatively poorly developed and the feature is seen to become less prominent in this direction. This strongly suggests that it continues to the north of the exposures in Stobgreen Sike. In Lunedale, the Grit Sills (or Sill) were seen to thicken to the east, while current bedding directions suggest a northerly or, more frequently, an east north easterly source. If these current bedding directions are of any real significance then it seems reasonable to suggest either that the washout swings suddenly to an west south west direction in the Eggleston area, or more probably, that the main washout branches, with one branch, or distributary running towards Bail Hill. Whether this particular ribbon of sandstone dies out here, or whether we are merely seeing the edge of the wash-out is not clear. Reading notes that the Grit Sills decrease in importance to the south across Stainmore and die out south of the area. This probably means that the westerly attenuation in Lunedale takes place at the edge of a washout, or that other grit developments (probably ribbon developments) cross the area.

<u>Transgression Beds Grit and beds to the base of the Grindstone Sill. The Coalcleugh Transgression.</u>

<u>Newbiggin - Hudes Hope Area</u> - Carr Crags, on the eastern slopes of Flushiemere, is a prominent, boulder-strewn feature, with craggy outcrops of coarse grit belonging to the Transgression Beds Grit. Running south just above or below the 2000 feet contour, it swings around into the head of Bleagill Sike, dipping south easterly, and then runs in a southerly direction forming a spur called Weather Beds, the southern point of which lies at a height of approximately 1,860 feet O.D. The feature continues northwards up the western flanks of Hudeshope to Hudeshope Grains where we get our first measurable section of the grit. In one of the streams of the Grains (935319), 15 feet to 20 feet of fine to medium grained, buff, flaggy grit or sandstone, with some carbonaceous streaks, crops out. The nature of the grit is quite different from that seen in Carr Crags and in a small stream on Weather Beds (929305) where it is pebbly and dips almost due south at 6°. This illustrates the varied nature of the grit. Some sandy, micaceous shale and micaceous

sandstones are exposed below the Grindstone Sill in this stream in the Grains. The feature, still prominent, runs in convex arcs between the various streams of the grains until the grit is thrown up approximately 10 feet to 15 feet to the north by the almost east - west Hudeshope Head Vein, to be exposed in one of the branches of the main easterly branch of Hudeshope Beck (938322) as a flaggy, medium-grained, white sandstone with plant remains (No.179). In common with the lower features on the upper eastern slopes of Hudes Hope, the Transgression Beds Grit feature is lost sight of for 100 yards or so, but thence can be traced south south eastwards, with boulder strewn crags of coarse, current bedded, buff grit (No.112) up to 10 feet or 15 feet thick at High Carrs (942311) and Low Carrs (948303). The feature descends from a height of approximately 1,775 feet O.D. in the north to 1,700 feet O.D. in the south near the Lodgesike - Manorgill Vein. The base of the shale feature above has been taken as the top of the grit. Exposure of succeeding beds below the Grindstone Sill is very poor, with 7 feet to 8 feet of grey-buff, micaceous shale immediately below the Grindstone Sill exposed at the tip of Carrs Hill (955303), and some fine to medium grained, flaggy, micaceous sandstone 400 yards to the south east.

South of the vein, the Transgression Beds Grit forms a prominent feature, with the throw of the vein apparently small, but reversed in this locality. The block of country between Lodgesike and Manorgill south of this vein, is in fact uplifted relative to the area to the west, by the combined efforts of the north north west - south south east fault running to Eggleston Burn (p. 394) and the north east - south west fault (p. 398) running to join the Lodgesike - Manorgill Vein west of Great Eggles Hope. The feature, running south at approximately 1725 feet O.D., has exposures of coarse, flaggy grit, and was quarried immediately south of the Lodgesike - Manorgill Vein (959297), where the grit is very coarse and limonite-stained. Recognition of this grit as the Transgression Beds Grit depends upon the occurrence of a fossil sandstone below it which can only be referred to the Rookhope Shell Beds. Also, the beds are obviously faulted here, as is made evident by the interruption of features; if the downthrow was to the north, then the feature -forming Fourth Millstone Grit would be seen to the north, as it is to the south of the fault. It is not, so one must conclude that the downthrow is to the south, preserving the grit scar of the Fourth Millstone Grit on Monks. The top of the grit has been taken at the base of a fairly prominent feature running in a semi-circle north of Monks. A fine-grained, micaceous, olive-coloured sandstone underlies 4 feet of grey, micaceous, shales cropping out above the base of the feature in a small northerly flowing stream. The base of the Grindstone Sill is purely conjectural, no exposures, or features occurring to suggest its position, through the peat. A higher feature has been taken as marking the base of the First Millstone Grit, with approximately 50 feet separating this and the top of the Transgression Beds Grit. This interval seems sufficient to house the Grindstone Sill and associated beds and the former has been drawn in conjecturally. This may not be the case, however, and the"First Millstone Grit" feature may in fact be the Grindstone Sill. The Transgression Beds Grit outcrops in the head waters of Manorgill Sike as a very coarse, buff grit (No.111) overlying some poorly fossiliferous shales. From the stream a relatively weak feature runs east south eastwards for 200 yards before dying out in the peat.

Approximately 760 yards south of the vein, the Transgression Beds Grit is downthrown by the north east - south west fault between 100 feet and 130 feet, but a drift patch obscures the solid geology below the First Millstone Grit feature. Beyond the north north west - south south east fault the grit once more comes to light, approximately 700 yards to the south west. A feature runs around Brown Dodd, with exposures of coarse grit. It fades on approaching the conjectured line of the Aukside Vein, but reappears beyond the headwaters of Snaisgill Sike to run south and then south south east to Black Edge (962268) and Knott Well (969266). Numerous exposures of coarse and very coarse, current-bedded, loosely cemented grit are seen, particularly at Black Edge (No.9) in some old quarries and scar exposures, and in some old quarries west of Knott Well, where at least 15 feet of grit is exposed. Current-bedding directions at the latter locality indicate a north westerly source. Beyond Knott Well, the feature, now drift skirted, swings northwards, at a fairly constant height above the 1250 feet contour, with some coarse grit (No.132) exposures in old quarries. Nothing is seen of the overlying beds up to the Grindstone Sill.

<u>Eggleston Burn, Great Eggles Hope, Little Eggles Hope.</u> - North of Slaggy Sike, near the old quarries mentioned above, the Transgression Beds Grit is once more upthrown by the north north west - south south east fault met with in Hudes Hope, and which runs, now in a north west - south east direction, to Knotts Hole (995263). The feature continues northwards, and in

one of the branches of Horden Sike, the grit, coarse grained (No.135), is seen in an old quarry (977277) and a few yards upstream, 2 feet of grey shale is succeeded by 18 inches of grey shale with coal streaks, and 1 inch of sandy shale passing up into a flaggy, fine-grained buff sandstone dipping south east at 7°. Northwards the feature remains prominent, with constant exposures of grit, coarse, to fine grained, limonite-stained and current-bedded, with a north north westerly source prominently indicated in one (979284). In East Rake Hush, 20 feet of coarse limonite-stained, current bedded (north north westerly source) grit (No.142) crops out, with further exposures to the north in West Rake Hush (where it takes the form of a fine grained, flaggy buff sandstone), and the streams running between the two hushes. (No.145). In the stream, a thin ganister over some grey, micaceous shales dipping north at 5° represents the only exposure of the overlying beds seen since that in Horden Sike over a mile to the south. Judging from the attitude of the overlying Grindstone Sill feature, intervening beds appear to be somewhat attenuated as we come northwards.

On the eastern flanks of Eggleston Burn the Transgression Beds Grit is largely hidden beneath drift, but a feature does peep through in two places: south east of East Skears, and below Brown Dodd, on or near the 1250 feet contour, serving to check its position below the prominent Grindstone Sill - First Millstone Grit feature. In Little Eggles Hope the grit once more appears, first being seen as a fine-medium grained, massive sandstone with plants, 12 feet being exposed. Thence it floors and flanks the stream for approximately 530 yards to the north, with one dip of 12° being recorded (994297). The final exposures in the stream bed reveal a medium-grained, mottled sandstone with calcareous cement (No.149).

In an old quarry on the right bank (993300) a good section of the succeeding strata presents itself. A 4 feet fine grained, micaceous sandstone is capped by a 30 inches cream ganister with plant fragments (No.150), and above this, 2 feet 6 inches of shales and sandstones, capped by the Upper Felltop Limestone (No.150 and 151). This latter consists of a famped, fossiliferous limestone passing down into a quartzite, totalling 12 inches to 18 inches, and is succeeded by some fossiliferous black shale, (No.152). A gap of up to 5 feet or 6 feet occurs between the Transgression Beds Grit and the basal sandstone in the quarry, but some fossil shales (No.154) are exposed above the grit 200 yards downstream. 70 yards to the north the limestone is exposed as 12 inches, limonite-stained, sandy limestone, in the stream, overlying at least 2 feet of fine grained flaggy micaceous sandstone. The limestone has a peculiar "oolitic - like" appearance, due to the abundance of quartz grains, which in thin section, amount up to 15% or more of the rock. The carbonate is of a yellowish colour and has the optical properties of siderite (giving limonite) in the main, though clear patches of calcite occur accounting for the brisk effervescence when dilute H.Cl. is applied to certain parts of the rock. The siderite is very fine grained with all the characteristics of recrystallization, and this, together with minute traces of iron pyrites suggest the influence of mineralization processes. No veining is seen nearby, but 600 yards upstream the East Rake Vein crosses Little Eggles Hope. A second 6 inches to 9 inches fine grained greenish-grey, micaceous limestone outcrops in the stream 210 yards to the north, and finally, a further 90 yards upstream, in the right bank, the Grindstone Sill caps some sandy shales which grade down into fine grained, grey, poorly fossiliferous shale (No.168).

North of the Flake Brig Vein in Little Eggles Hope, the succession is repeated and the Upper Felltop Limestone (No.165) is exposed in a gutter running for 140 yards to the south east, 240 yards south east of Little Eggles Hope Mine, on the left bank of the stream. It is 4 feet 9 inches thick, consisting of fossiliferous, blue-grey limestone, passing down into a fine grained sandstone. Beneath, 9 feet of sandy shale with a 6 inches sandstone, overlie some calcareous grit (No.164), which possibly represents the top of the Transgression Beds Grit. In the steep hillside running southwards from Little Eggleshope Shop (987313), the Grindstone Sill overlies at least 30 feet of sandy, micaceous shale, with impersistent shaly, micaceous sandstones.

Below Middle End (987294), the Transgression Beds Grit forms a prominent feature, readily traced to the north west along the eastern slopes of Great Eggles Hope, to Wiregill Mine. An old quarry reveals some fine to medium grained buff sandstone with large plants (986293), and a ¼ of a mile further north, a fine grained, limonite-stained, micaceous sandstone outcrops immediately south of East Rake Vein. The downthrown feature (10 feet north) runs north west for 700 yards to the Flake Brig Vein which throws the grit up the level of the Grindstone Sill on the north. The fault is revealed at the head of Dusty Gill (981304) where medium to coarse grained, flaggy, micaceous grit near the top of the Transgression Beds Grit, is brought up against the base of the First Millstone Grit and some underlying shales. A feature runs in a northerly direction and swings round in a concave arc to the head of Wire Gill, above the old lead level (977310). An old quarry reveals a few feet of flaggy fine to medium grained, buff sandstone (978310). In the western branch of the stream at the head of Wire Gill, the Transgression Beds Grit has become a very coarse grit (No.160) once more. A good feature runs around the top of Round Hill, until interrupted by the Little Eggleshope Vein. The feature runs up the contours on the eastern slopes of Great Eggles Hope to the vein. North of the vein, the upthrown grit (approximately 25 feet to 30 feet) makes a prominent feature running north west, with some loose blocks of coarse to medium grained grit and sandstone. At Grey Stones (961318) coarse grit up to 10 feet or so outcrops, but just over a quarter of ¼/a mile to the north, the feature ends abruptly south of a small tributary stream. Sixty 60 yards to the east, the grit outcrops in High Grey Stones (959322), being upthrown by a north west - south east fault, which is revealed by high dips of 20° west south west in Great Eggleshope Beck to the north west. Nothing more is seen of the horizon until upwards of 15 feet of flaggy, fine to medium grained sandstone (No.157) crops out in the beck. Except for some soft, sandy, buff shale below the Grindstone Sill seen in the beck, the overlying beds remain concealed beneath thick peat

On the western slopes of Great Eggles Hope, the Transgression Beds Grit is exposed as 15 feet of fine grained, flaggy, micaceous sandstone in the first stream south of White Swangs (954324), and as a coarse grit in the next but one stream to the south. No feature appears through the thick peat cover until beyond

Arngill Sike. From here, just below the 1,750 feet contour, a feature runs south, south east for 700 yards marking the base of the grit, with a second feature running south south east for 900 yards probably marking shales and sandstones above, and taken as the top of the grit. No exposures occur in Arngill Sike or the forked Lodgegill Sike.

The only further indications of the grit to the south, are a feature taken as marking the top of the grit, and in which 10 feet of sandy, micaceous, grey and buff shales are exposed, above Manorgill; and coarse to medium grained, flaggy, micaceous grit and sandstone outcropping in the old hushes north of the Lodgesike - Manorgill Vein. In the northernmost hush, the grit dips south east at 31° towards Manorgill North Vein, which does not affect the overlying feature.

<u>The Eggleston District.</u> - In the Blackton Beck area, a Transgression Beds Grit feature runs south east from Moor House (989260), south of the Knotts fault, to north of the old reservoir (997256) of the Blackton Smelting Mill, where it disappears beneath drift. Up to 15 feet of coarse grit is exposed in some old quarries at Moor House, and in one, 30 yards or so north of the house, the grit is overlain by some fine grained siltstone (No.89), which has been baked by the Whin Dyke intruded along the line of the fault. Nothing further is exposed either of the grit, or the overlying beds. South of Blackton Beck, the grit feature, with an old quarry revealing some medium grained grit (000251), reappears through the drift to form Blaeberry Bank, but rapidly disappears beneath the drift on Nemour.

Our next view of the Transgression Beds Grit is in Stobgreen

Sike, where 50 feet to 55 feet of grit (No.282), varying from fine to coarse, pebbly texture and containing some ironstone nodules and a patchy calcareous cement, crops out. Situated in a wedge of country between the Northern Eggleston Fault, and a branch of this fault to the south (not to be confused with the main Southern Eggleston Fault), the grit dips north north west at 50°. This is by far the greatest thickness seen in the grit, its identity being established by the underlying Rookhope Marine Band (see p. 157). Some shales, a 1 foot ganisteroid sandstone, and a 1 foot thick buff sandstone are the only beds exposed above. South of the southern (Town Head) fault, a bold feature formed by the downthrown (20 feet) grit, runs southwards until interrupted by the Southern Eggleston Fault. 9 feet of fine to medium grained grit are exposed in a small stream just north of the latter fault (007236). Above, a second, powerful, drift- Colley Hill capped feature reveals an exposure of 10 feet of current-bedded grit, our first glimpse of a higher grit between the Transgression Beds Grit and the Upper Felltop Limestone. This is terminated on three sides by faulting: on the north west by the Town Head Fault, on the south by the Southern Eggleston Fault, and on the east by a north north west - south south east fault, bringing the top of the Grindstone Sill on the east level with the top of the grit on the west.

The Southern Eggleston Fault brings the Transgression Beds Grit down to river level at Eggleston Bridge. At the mouth of Hell Beck, the top 9 feet or 10 feet of the grit (No.257), medium to coarse grained, and with a liberal calcareous cement near the top dips north west at 10°, disappearing into the Tees 35 yards north of the bridge in the steep left bank. Above, 10 feet of black, silty shales are capped by up to 50 feet of coarse, current-bedded grit. On the southern bank of the Tees, 3 feet or 4 feet of flaggy, medium grained, grey grit is exposed in an old water course, belonging to the lower Transgression Beds Grit. Apart from this, the beds are completely obscured beneath thick drift, along the right bank, until we reach Skirtle Bank, where 14 feet to 15 feet of coarse grained, current bedded grit outcrops in the mouth of a small stream.

South of Eggleston Bridge, the two grits form the steep slopes of Great Wood above the alluvial tract east of the Tees, with 8 feet of coarse, grey grit exposed in an old quarry. The grit, which belongs to the lower of the two (the Transgression Beds Grit) is current-bedded and contains carbonaceous plant remains, ironstone nodules and has some shaly partings. 360 yards south east of the bridge, the Black Sills fault (see p. 157) throws the Transgression Beds Grit up approximately 20 feet or so. The fault can be picked up again to the north, near the confluence of Nab Gill and Hell Beck (000234) where dips of 24° north north west and 30° north occur, west and east of the fault respectively. Immediately east of the fault, the base of the Transgression Beds Grit overlying some silty shales is exposed, and 110 yards upstream the shales above, the grit outcrop in the stream, south of the Southern Eggleston Fault.

The Transgression Beds Grit outcrops almost continuously along the eastern bank of the Tees, south of the Black Sills fault, with at least 40 feet of coarse grit revealed in an old quarry and the stream running north of West Barnley. Intermittent exposures in the stream continue up to a point west of West Barnley farm. 170 yards downstream from the quarry, the grit forms an extensive cliff-like feature in the left bank of the Tees. 32 feet of the grit (No.259), is exposed, as a coarse, micaceous grit with a patchy calcareous cement. The base of the grit descends from 650 feet O.D. , to 600 feet O.D., opposite Skirtle Bank, dipping in a southerly direction into the north eastern flanks of the Stainmore Syncline.

The top of the grit, south of Nab Gill, is conjectural, although exposures of coarse grit 240 yards north west and 70 yards west of West Barnley (004229) serve as checks. In the east - west stream north of East Barnley (008229) a useful section from the Transgression Beds Grit to a fossil sandstone hitherto not seen in the area, occurs. Above the final exposure of the grit, at least 10 feet of silty, grey shales are capped by 30 feet of fine to medium grained, current-bedded grit or sandstone with a patchy calcareous cement (No.306). Source directions are variable, some indicating a north westerly source, others a south easterly source. A sigmoid feature runs northwards from the stream, to be interrupted some 1,400 yards to the north by the Southern Eggleston Fault. 2 feet of medium grained grit is exposed in the stream 200 yards west of Mount Pleasant farm (005231), the remainder being concealed beneath the drift covering, Handkerchief Plantation and Barnley. To the south of East Barnley, drift hides the grit feature, but 25 feet of fine to medium grained shaly sandstone, becoming flaggy downwards, outcrops in Raygill Beck (009218) overlying 3 feet of silty grey shale. Above the sandstone over 20 feet of sandy shales with some thin sandstones, and capped by a 4 feet to 4 feet 6 inches fine grained buff sandstone, are exposed below 9 feet of limonite-stained, grey, sandy limestone, which grades laterally and vertically (not uniformly) into a calcareous sandstone. A typical, steep sandstone capped-shale feature, the true course of which is masked by drift, runs northwards, with a subsidiary feature at the top caused by the sandstone or limestone, which can be traced northwards for over 160 yards. The limestone, rising slightly to the north, is exposed again in the stream, some 30 yards above the sandstone quarry near East Barnley. Its character is somewhat changed, being represented by 3 feet of sandy, limonite-stained, shelly limestone (No.307) grading down into 3 feet of flaggy calcareous, grey sandstone. This in turn passes down into 5 feet of sandy shale above silty grey shales with ironstone nodules. Approximately 100 yards downstream from the fossil sandstone, 5 feet of thin grey sandstones and sandy shales, with a thin (2 inches or 3 inches) shelly, sandy, grey limestone outcrop, the latter being referred to the Upper Felltop Limestone by H.G. Reading (1954,p.116).

North of the stream, patchy drift obscures the solid geology, but some loose pieces of calcareous sandstone, occur where one would expect to find the sandstone, in Handkerchief Plantation (009227). A feature, obviously formed by this fossil sandstone over fairly thick shales, runs northwards from the stream for a distance of over 660 yards, rising from about 870 feet O.D., at the stream to 900 feet O.D., at its northern end. Apart from an isolated exposure of fine grained sandstone and some loose silty shales, nothing is seen of the succeeding beds until some scattered outcrops of the Grindstone Sill near Windy Hill farm (017223).

In Pallet Crag Sill to the east, the fossil sandstone, which is upfaulted at this point (025229) outcrops as 9 feet to 10 feet of flaggy, calcareous sandstone, (No.297) dipping south east at 8^{o} into the fault. It outcrops in the stream for a distance of over 200 yards. Above, exposure is sporadic, but an estimated 60 feet or so of silty, nodular shales, with thin sandstone ribs, occurs beneath the Grindstone Sill.

Reading's interpretation of the geology of the Eggleston area was somewhat different to that presented above. He mapped three Transgression Beds Grits, referred to as the pebbly grit, the middle grit, and the upper grit, the top two of which coalesce near Eggleston Bridge (p.95). Apparently, near Barnard Castle all of them thicken and probably the lower two grits also merge. According to his mapping of this part of the Tees, however, it is the two lower grits which merge, with the upper grit remaining distinct, and the Fossil Sandstone is drawn in conjecturally, close above. The grit outcropping near the mouth of Hell Gill (herein mapped as the Transgression Beds Grit) he regards as a grit or sandstone immediately below the Lower Felltop Limestone (presumably the calcareous top of the grit represents the limestone) - "At Eggleston Bridge, one mile from the first mentioned outcrop, the disconformity is lifted to expose 5 feet between the bases of the pebbly grit and the Lower Felltop Limestone". "Pebbly grit" here refers to the second, 50 feet to 55 feet grit outcropping in the stream. Apart from the fact that the Lower Felltop Limestone downstream is not remotely like the calcareous sandstone seen in Hell Gill, no grit comparable to that seen near the bridge occurs below the limestone in the Tees, downstream.

The Black Sills fault is not continued beyond the river by Reading, and does not affect his pebbly grit (the Transgression

Beds Grit of this account). The throw of his fault is slight, and down west. The sandstone outcropping in the Tees between Black Sills and Tophet Hole, and the lower grit at Eggleston Bridge are obviously regarded as the same horizon. The change in lithology of the sandstones presents no difficulty, but no explanation is given for the beds occurring between this sandstone and the Lower Felltop Limestone east of this fault, a series of shale, mudstones, siltstones, ganisters and chert amounting to 40 feet or so. At Eggleston Bridge the "Lower Felltop Limestone" lies directly on the sandstone. Below the old quarry previously mentioned, in the stream from West Barnley, the Transgression Beds Grit (or pebbly grit) overlies:

		Ft.	-	Ins.
Shale.		0	-	10
Limestone (basal limestone of Lower Felltop Limestone Group)		1	-	4
Ganisteroid sandstone.		1	-	6
Shale.	7 ft. to	8	-	0
Gap.		8	-	0
Grey ganister.		1	-	0
Gap.		2	-	0
Tough, micaceous, grey siltstone.		2	-	0

Immediately west of the fault, at Black Sills, in the right bank of the Tees near river level (i.e. about 20 feet lower), a 1 feet ganister overlies 5 feet 3 inches of tough, slightly micaceous, shaly siltstone. No other 1 feet ganister is seen in the succession in the Tees, and it seems perfectly reasonable to regard the two exposures as representing the same ganister, one on each side of a visible fault with a westerly downthrow of approximately 20 feet. The grit at Eggleston Bridge can be traced downstream to the fault, and is upthrown 20 feet west to be exposed in the quarry. This would do away with the necessity of explaining the disappearance of 30 feet of strata below the "Lower Felltop Limestone" in Hell Gill, which bears no lithological resemblance to that seen downstream, and which Reading says is "very constant" (p. 159).

Objections may be raised towards identifying the the second, upper grit as the upper grit encountered on Stobgreen, on the grounds of big thickness differences - 50 feet to 55 feet as compared with 10 feet (exposed) on Stobgreen, and 30 feet and 25 feet on Barnley. But if we invoke a roughly east - west belt of thick sandstone development (such as appears to occur in the Grit Sills in this area, pp. 172-73) this difficulty is overcome; in any case, it is no more difficult to explain than the re-appearance of the beds between the Grit Sills and Transgression Beds Grit in Stobgreen Sike, amounting to 25 feet to 30 feet. These beds can be correlated with the sub,-Lower Felltop Limestone strata in the Tees, despite the absence of the limestone itself through transgression. A north - south thinning south of the belt, which would be implied by advocating an east - west ribbon development of sandstone, is seen on Barnley between East Barnley and Raygill Beck, the upper grit thinning from 30 feet to 25 feet and becoming finer grained and shaly in the latter exposure. Reading has linked this latter sandstone with that in Nab Gill, herein regarded as the upthrown Transgression Beds Grit (pebbly grit) apparently ignoring the grit feature and the course of the fossil sandstone.

Three grits do apparently occur in the Tees to the south, with a coal (correlated by Reading with the coal in Shields Beck and Wady Carr Sike - pp. 191-192) occurring between the pebbly and middle grits. It is not denied that the lower grit may split, to form two separate grits to the south, but there is definitely no sign of this occurring north of Raygill Sike. In the stream north of West Barnley, Reading records 12 feet of grit in the quarry, and 10 feet of grit directly overlying the Lower Felltop Limestone below (with a conjectural gap between them), respectively representing the middle and pebbly grits. This means that the pebbly grit is not much thicker than 10 feet here, a somewhat drastic and highly localized attenuation.

The Primary Survey's interpretation was comparable to that adopted by the author, except that the beds were classed as "Millstone Grit". They mapped two grits, the upper grit running below Handkerchief Plantation, through East Barnley and following much the same course as that mapped in the present survey. The lower grit was mapped along the left bank of the Tees, extending on to Barnley, agreeing with the present interpretation. They also mapped a coal within the lower grit south of Great Wood, where the present survey ended, which supports Reading's belief that the grit does divide, but approximately 1 mile further south than he suggests.

Lunedale. - The first significant exposure of the Transgression Beds Grit in Lunedale occurs in an old quarry near Wady Carr Tile Works, where 27 feet of medium to coarse grained, current-bedded grit (No.255) dips south at 6°. The current bedding directions indicate a northerly source. To the east, drift conceals the grit completely except for some coarse, flaggy grit cropping out in a small tributary stream of Hole Beck, immediately north of Fell Lane, 300 yards east of Tin Ten (983219). An outlier caps Hayberries Plantation north of Grace's Cottage, 5 feet of coarse, to very coarse, current bedded grit (No.252), dipping south east at 6° being exposed 270 yards north north east of the cottage. Current bedding indicates a northerly source. The grit runs along the top of the steep southern bank of Wady Carr Sike as far as Bail Hill Road, with frequent exposures of flaggy, medium grained, micaceous grit, with calcareous cement in places.

The grit is then lost sight of until we reach Toddyshaw Hill where numerous grit blocks testify to its presence. In Shields Beck, which cuts through the grit to separate Toddyshaw Hill on the east from Black Rigg on the west, but a few feet of flaggy grit are exposed, while shallow, overgrown quarries on Black Rigg with some loose coarse grit flags and some in situ exposures (No.312) bear witness to the fact that the grit is thinning rapidly to the west. The top of the grit is taken at the base of the dip slope feature south of Black Rigg, where it dips under the marshy ground below Parson's Rigg. To the west the grit is downthrown by the West Pasture Road Vein. A feature, with some old, shallow grit quarries runs towards Easter Beck beyond the vein, petering out completely before reaching the beck, the grit having died out.

But crop shown as crossing Beck.

Above this, a feature with some grit exposures runs around to the West Pasture Road Vein (which appears to be dying out to the south east) where it steps back and then runs east north east, forming Parson's Rigg. A quarry on Parson's Rigg (964222) affords an excellent section of this upper sandstone - grit. 22 feet of medium grained, current bedded sandstone (No.313) with 1 foot of sandy shale and sandstone, 2 feet from the top, dips south at 10°. A north easterly source is indicated for the sandstone. Above, 2 feet 6 inches of sandy shale passes up into an 18 inches fireclay capped by a 1 feet coal and sandy shale. Bail Hill quarries to the east reveal up to 24 feet or more, of current bedded, medium grained grit (No.309) dipping south south east at 4°. Current bedding here suggests a southerly source. The base of the sandstone or grit is not revealed in any of these quarries, so that the full thickness is not known (Reading estimated over 50 feet, but this seems excessive). Numerous other old quarries occur in this horizon, which forms a bold feature at a fairly constant height of 1,175 feet O.D. until we reach Bail Hill Quarries, east of which it descends to 1,000 feet O.D. 600 yards east of Bail Hill Road, where it disappears beneath the drift. Near the eastern extremity of the feature an old quarry (979222) reveals 10 feet to 12 feet of medium to coarse grained, current-bedded grit, regarded by Reading as the top of the lower grit. The author cannot agree with this however. First of all, the feature of the higher sandstone - grit can be traced almost to the quarry; secondly, the dip of the lower sandstone in the quarry near the Tile Works, 200 yards north north east of this quarry, would carry it below this quarry. The top of the grit can be accurately mapped between the Parson's Rigg and Bail Hill quarries, elsewhere it is inferred. No succeeding beds are exposed below the Grindstone Sill.

Reading regarded these two horizons as representing his upper and middle Transgression Beds Grits. The identification of the lower member as the middle grit is based on the presence of a coal below, which he correlates with that occurring below the middle grit in the Tees and elsewhere. The presence of the Upper Felltop Limestone, and the Fossil Sandstone above the grit on the southern side of Botany (in How Gill) (Reading 1954, see p. 102) establishes the identity of the upper grit. The pebbly grit, seen on Toddyshaw Hill and elsewhere, is not equivalent to the horizon mapped as the Transgression Beds Grit in this survey. Unfortunately, nothing is seen in the critical area between the Tees and the Northern Teesdale Fault, where the grit presumably peters out. It would appear simpler to regard the lower grit at Eggleston Bridge and that on Toddyshaw Hill and Black Hill Plantation, as one and the same, becoming thinner towards the west, and possibly, like the grit in the Tees, dividing into a pebbly and middle grit to the south. This however, does not take into consideration the Shields' Beck - Wady Carr Sike coal. No coal development has been seen in a similar position above the Lower Felltop Limestone elsewhere in the area, which supports Reading's correlation of this coal with that below the middle grit in the Tees, and elsewhere in Stainmore.

<u>Sharnberry Gill, Euden Beck, South Grain Beck, and Ayhope Beck.</u> - The Transgression Beds Grit is not exposed in any of these stream sections, but some good exposures of the succeeding beds are seen.

Outcrops below the Grindstone Sill in South Grain Beck are spasmodic, but one section (031315) shows some black carbonaceous shales below the sill, overlying a coal smut, a 2 feet ganister, 6 inches of dark grey limestone, and 8 feet of shale, the lower few feet of which are poorly fossiliferous. The limestone is possibly one of the Upper Felltop Limestone group. A north north west - south south east fault running through Black Hill crosses the beck east of the Loop (035314), throwing the succession down 20 feet or so to the east. Exposures below the Grindstone Sill are again sporadic, with shale a thin ganister, and a 6 inches coal being seen. The coal may be equivalent to that upstream, but this is by no means certain.

500 yards east of the Meeting of the Grains (057315), 10 feet to 12 feet of flaggy, fine grained, buff sandstone is exposed in the right bank of Ayhope Beck. Further outcrops of the sandstone occur downstream, in the right bank only, and 65 yards west and 150 yards east of the mouth of Hawke Sike Gill (064314), cliffs in the right bank reveal up to 25 feet of fine to medium grained, micaceous, buff sandstone, with 4 feet of silty grey shale beneath. This sandstone may be equivalent to that one occurring above the Transgression Beds Grit in Lunedale and the Eggleston area. No evidence is forthcoming from this area concerning the relationship of this upper sandstone or grit, to the Coalcleugh Marine Beds. The only possible exposure of this latter horizon occurs in Little Eggles Hope, where some poorly fossiliferous shales (No.154) occur close above the Transgression Beds Grit, and 10 feet - 15 feet below the Upper Felltop Limestone - but no upper sandstone is developed here. Reading, however, has sufficient evidence in the Stainmore area to place the sandstone above the Coalcleugh Marine Beds, leaving his pebbly grit below. The middle grit is apparently transgressive, removing the marine band in the areas where it is developed. Dunham (1948,p.41) refers to a sandstone called the Hipple Sill, or Low Grindstone, which is developed between the Coalcleugh Marine Beds and the Upper Felltop Limestone i.e. in the same position as this upper sandstone. The Hipple Sill is also stated to be followed by "sandy shale or grey beds overlain by flagstones with plants. The flagstones pass into ganister at the top,on which rests a thin coal or smut" (p.41). This coal compares with that occurring above the upper sandstone in

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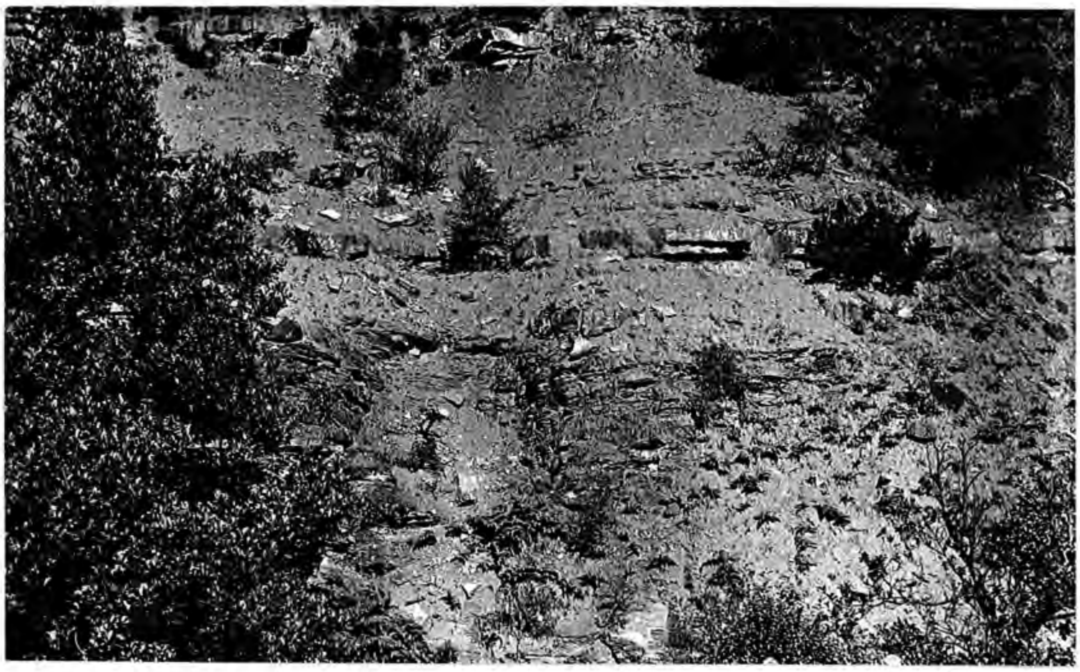
Plate 6.



The "Upper Felltop Limestone", Redgate Shields, Sharnberry Gill. The section reveals a series of alternating shales, thin limestones and thin sandstones.

Parson's Rigg Quarry (see p. 190). There seems no reason, therefore, why one should not correlate this upper sandstone or grit with the Hipple Sill of Hunstanworth and the Low Grindstone of Killhope Law Ridge, with the former name being adopted.

In Sharnberry Gill to the south, the first useful exposures of sub- Grindstone Sill beds are seen in the bend where the stream first swings southwards from its east - west run. Here, 30 feet of shales occur below the Grindstone Sill, with a fossil band (No.197) 15 feet to 20 feet below the sandstone. A 4-feet sandstone over shales comes beneath. The succession on the opposite bank shows more sandstone, one 3 feet sandstone, 19 feet below the Sill, separated from a lower 8 inches sandstone by 2 feet 6 inches of sandy shale. 270 yards downstream (024308) a flaggy, cream, fine grained sandstone outcrops with a "crust" of fossiliferous limestone a few inches thick, the Upper Felltop Limestone. The fossil shales below the Grindstone Sill are probably equivalent to those seen in Little Eggles Hope (p. 179) and might well be correlated with the Fossil Sandstone seen to the south and south west.

The Upper Felltop Limestone can be seen in one or two places downstream in the right bank, together with some shales and thin sandstones. At Redgate Shields (031297), however, the "Upper Felltop" horizon is seen to be somewhat more complex. An 18 inches limestone, haematite stained and fossiliferous at the top, grades down into a 6 feet 6 inches sandstone overlying a 3 feet bed consisting of sandy limestone passing down into fine grained sandstone. Below these, 13 feet 8 inches of shales with thin limestones (one 2 feet thick) some of which are fossiliferous, are underlain by thick shales. The two upper horizons and the

13 feet 8 inches shale - limestone succession can be grouped together as the "Upper Felltop Limestone", and any one limestone outcropping could be identified as the Upper Felltop. The two topmost beds are probably more persistent, or at least outcrop more readily, as most exposures of this horizon consist of limestone grading down into sandstone.

Further limestone exposures occur at the confluence of Morton Shields Beck and Cloudlam Beck (021295), where a thin fine grained blue-grey, haematite stained, fossiliferous limestone grading down into a fine grained sandstone, totalling 16 inches, crops out. Above, 10 feet of sandy, micaceous, shale, and 10 feet of fine grained sandstone are capped by 23 feet 6 inches of shales with two thin sandstones (one with plants), a 3 inches coal, and 2 feet of shale with coal smuts. 100 yards downstream from the confluence, we see a sandy limestone passing down into a fine grained sandstone, totalling 3 feet over 3 feet of shale and fine grained ganister. This probably represents the lower limestone - sandstone horizon of Redgate Shields, but no comparable ganister was seen at the latter locality, testifying to the variability of this part of the succession. The 10 feet sandstone outcrops sporadically downstream. On the 900 feet contour, in the right bank of Cloudlam Beck, an 8 feet 2 inches bed of limestone grading down into sandstone crops out, probably representing the top limestone of Redgate Shield. Acton Beck also offers us glimpses of the Upper Felltop group, a thin dark limestone over a 6 feet sandstone occurring 200 yards from its mouth, and a 1 foot crinoidal limestone on a 4 feet 6 inches ganisteroid sandstone in the right bank near its confluence with Sharnberry Beck. Above the limestone in the latter exposure, 9 feet of fossiliferous shale is capped by a 6 feet fine grained sandstone. This fossil shale may, or may not, be equivalent to that seen over a mile upstream in Sharnberry Gill. 800 and 1,300 yards downstream we have a 10 inches sandy grey limestone over a 5 feet fine grained sandstone, and a 6 inches limestone capping a fine grained quartzite respectively, dipping east at 3° to 4°. Little else is exposed below the Grindstone Sill until Kings Crag (see fig. 3d ,p. 74). A 3 feet 6 inches fossil shale occurs 10 feet below the Sill and is probably equivalent to that seen upstream in a similar position, while a coal smut above a 2 feet micaceous, ganisteroid sandstone, 22 feet below the Sill may well be the same as the 3 inches coal occurring in Cloudlam Beck. The beds here dip west of south at 5°. 100 yards downstream, a 1 foot fossiliferous, famped limestone (No.282) rests on 6 feet of fine grained sandstone, and is probably the top member of the Upper Felltop Group. Apart from some shales and sandstones exposed in the left bank of Euden Beck, below Paddy's Plantation (064301), and in an old gravel pit south of The Grove in Spurlswood Beck (066299), nothing more is seen below the Grindstone.

<u>The Coalcleugh Transgression</u>.- The extent of the transgression below the Coalcleugh Transgression Beds Grit is reflected by the absence of the Lower Felltop Limestone, where this is proven. In the Newbiggin area, non-exposure of key horizons below the grit prevents us from ascertaining whether the transgression is active or otherwise. In Hudeshope Grains, to the east, a thin limestone does outcrop in the streams (see pp. 148-149), but the true identity of this is not certain; it may represent either the Lower Felltop Limestone or the Rookhope

Shell Beds. Remaining strata between the High Grit Sill and the Transgression Beds Grit are concealed, but approximately 30 feet of unexposed ground occurs above the limestone, so that even if the latter does belong to the Rookhope Shell Beds, the Lower Felltop Limestone may be present above.

The first positive signs of transgression occur north of Low Monks, on the eastern flanks of Hudes Hope, where a shelly, ferruginous grey sandstone belonging to the Rookhope Shell Beds crops out a matter of 10 feet or less, below the Transgression Beds Grit. The Lower Felltop has evidently been removed. To the east, in West Rake Hush, the transgression has lifted, to preserve rather more than 26 feet of shale with one thin sandstone above the Rookhope Shell Beds. No limestone is seen, but some unexposed ground occurs below the Transgression Beds Grit itself, so that the Lower Felltop Limestone may possibly be preserved, though not seen. Still further east, in Wire Gill, the grit has descended somewhat, to allow the preservation of no more than 15 feet of strata above the Rookhope Shell Beds, so that non-exposure of the Lower Felltop Limestone here probably means its absence. To the south, drift obscures all the relevant sections until we reach Stobgreen Sike, so that it is impossible to draw any conclusions as to what happens below the Transgression Beds Grit.

In Stobgreen Sike, the Lower Felltop Limestone is once more absent, with 13 feet of shale preserved above the Rookhope Shell Beds. To the south east in the Tees, however, the transgression has lifted somewhat, near Black Sills, to preserve the lower limestone of the Lower Felltop Limestone group as it occurs in this area. Downstream the transgression continues to lift until the two limestone members occur, capped by over 11 feet of shale.

To the west, in Lunedale, the Transgression Beds Grit proper is not developed, and the Lower Felltop Limestone is present.

R.G. Carruthers (1938) related this transgression to that which he recognised below the Tanhill Grits. Chubb and Hudson (1925) however, considered that the Tanhill Transgression occurred below the Tanhill coal and ganister, rather than below the Tanhill Grits. Reading (1954) agreed with this latter suggestion on the basis of the widespread occurrence of a coal, which he correlated with the Tanhill or Kettlepot Coal, and which was nowhere seen to be actively transgressed, and is known to overlie a transgressive group (the pebbly grit). No coal horizon has been seen between the Lower Felltop Limestone and the Transgression Beds Grit, in this area, to justify classifying the Toddyshaw Hill grit with the Transgression Beds Grit as mapped in this area. While the Coalcleugh Coal itself is not seen, the 18 inches of coaly shale above the grit in Horden Sike undoubtedly represent this horizon. Reading's Middle grit, where developed, apparently either replaces, or removes both the Coalcleugh Marine Beds and Coal, both being restricted to the centre of his "mixed facies deposits". The pebbly grit occurs beneath these two horizons, and is evidently equivalent at least in part to the arenaceous beds mapped in this survey as the Transgression Beds Grit. If the middle grit arises through the mere splitting of the Transgression Beds Grit into two leaves, then the coal below the Middle Grit in the Tees, Shields Beck, Wadycarr Sike, and elsewhere is a seam not developed over the remainder of the present area. If however the middle grit is an

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entirely independent development, then the coal below it fulfills the requirements necessary for its classification, as the Coalcleugh Coal, and the pebbly grit is the equivalent of the Transgression Beds Grit. If, then, Readings correlation of this coal with the Tanhill Coal is correct the Transgression Beds Grit is equivalent at least in part to the Kettlepot Ganister, a correlation which supports the suggestions of Chubb and Hudson, and of Reading. Depending on whether the middle grit is an independent development or not, the Coalcleugh Coal may be equivalent to the Tanhill Coal. See 47? p.353

The nature of the transgression is dissimilar to that associated with the Low Grit Sill, the Rogerley Transgression, which appears to be largely confined to "washout" channels. The only definite occurrence of the Lower Felltop Limestone, apart from the Lunedale exposures, occurs in an area where the Transgression Beds Grit, and associated grits, attain their greatest development - the Tees below Eggleston. The available information suggests that the transgression is nowhere violent, comparatively speaking, within the area, but rather, a general, somewhat irregular transgressive plane. It must be remembered, however, that over large tracts of the area, both the base of the grit, and the underlying beds are concealed, so that the extent of the transgression is unknown. If known, the situation in these areas might modify this concept considerably.

The Grindstone Sill and succeeding beds to the base of the First "Millstone Grit".

The Newbiggin - Hudes Hope area. - Above Carr Crags, James's Hill is formed by a double feature, the lower member being the Grindstone Sill. The sill itself does not outcrop, 4 feet of grey shale over a 2 inches pyritous, micaceous grey siltstone (No.190) above the sill, being all that is exposed below the First Grit. The feature runs around into Hudes Hope, and in Hudeshope Grains we first see the Grindstone Sill, poorly exposed as a fine grained micaceous sandstone. In one of the streams, south of Hudeshope Head Vein (which is exposed in the stream) 5 feet of sandy grey shale are followed by a 9 inches coal and 20 feet of dark grey shale with some fossil fragments (No.183) some distance above the Grindstone Sill. Upfaulted against these, on the north, is a medium grained white quartzite (no.174) (4 feet of which is exposed) dipping south south west at 14°, capped by some sandy grey shale. A gap of a few feet follows until, just over 100 yards upstream, some black carbonaceous shale, succeeded by an 8 inches coal (equivalent to the 9 inches coal) and 9 feet of grey, micaceous and sandy shale, outcrop a few feet below the First Grit.

Why not mapped? Not shown

Around the head of Hudeshope Grains, the Grindstone Sill is unseen, but a short-lived feature occurs in the extreme north east of the valley, before it is downthrown by a north west - south east fault. South of this, a prominent feature, with frequent springs along its base, runs in a southerly direction as far as High Carrs before swinging south eastwards below Racketgill Head and Carrs Hill. The feature contains both the Grindstone Sill and the First Grit, the former being seen in many exposures of fine to medium grained micaceous sandstones. The First Grit is nowhere exposed through the thick peat, but some loose blocks of coarse grit occur 300 yards East of Low Carrs. A spring 400 yards north of Low Carrs, high up on the feature, probably marks the base of the First Grit, and gives us our only clue as to the respective limits of the sill and the First Grit, the top of the former and base of the latter being conjectural lines drawn in in relation to information obtained in Great Eggles Hope and this scanty piece of evidence. Nothing is seen of the intervening strata, but the fact that the First Grit doesn't form a separate feature leads one to suspect that they are not very thick.

South of the Lodgesike - Manorgill Vein, the slightly upthrown (see p. 194) Grindstone Sill probably occurs in a semicircular feature truncated on the south by the north east - south west fault running north eastwards from near Cat Level. ? location No exposures of the sandstone occur, and one might be led to believe that the overlying feature, regarded as belonging to the First Grit, is in fact the Grindstone Sill. There are no exposures in this higher feature either, but loose pieces of quartzite are abundant. These two features are separated by a vertical interval of approximately 50 feet however, which seems excessive for beds intervening between the Transgression Beds Grit (the top of which is marked by the lower feature) and the Grindstone Sill. In view of this, the Grindstone Sill is assumed to be present within the lower feature.

The sill is not exposed below the First Grit of Low Monks, but south of the north west - south east fault from Lodge Sike, a poor feature with some fine to medium grained sandstone outcrops runs south and then south east for a short distance on Brown Dodd. The lack of exposure south of the Lodgesike - Manorgill Vein, and the weakness of the feature on Brown Dodd, might mean ? location that the sill is poorly developed. Nothing more is revealed through the peat until Raven Hills to the south east, apart from a 6 inches ganister over some greenish sandstone occurring immediately below the First Grit at the source of Snaisgill Sike. This occurs north of the north west - south east fault, the exposure proving the continued existence of the fault. This exposure is our first glimpse of the green sandstone which is of widespread occurrence in the area, but whose usefulness is impaired by the presence of a similar sandstone below the Grindstone Sill in places.

At Raven Hills the sill forms a steep feature (capped in turn by the First Grit feature), the run of which is complicated by drumlin - like masses of drift. Some outcrops of fine to medium grained, flaggy, buff sandstone occur. The feature swings around in an arc, just below the 1,500 feet contour, until the sill is once more uplifted by the north west - south east fault. At the head of Druvy Burn, the base of the feature is marked by a remarkable line of springs. The sill is seen here to retain its fine grained sandstone character, but approximately 200 yards to the north, at the head of Slaggy Sike, a coarse grit facies (No.133) outcrops, with current bedding indicating a northerly source.

? [illegible] ? [illegible]

? [illegible]

Eggleston Burn, Little Eggles Hope, Great Eggles Hope. - Northwards from the fault, the Grindstone Sill feature runs just below the 1,500 feet contour until it meets the north east - south west fault north of West Rake Hush, in Great Eggles Hope. The head waters of Horden Sike reveal something of the beds above the sill. In one of the streams, a fine grained, flaggy, micaceous green sandstone, at least 2 feet thick (No.137), is exposed above the Grindstone Sill. 30 yards upstream some dark grey shales with ironstone nodules and a few brachiopods (No.136) occur immediately below the First Grit. This marine band is probably equivalent to that seen in Hudeshope Grains. (p.200) In the northern branch of the Horden Sike headwaters, 8 feet of shale, with ironstone nodules (but no fossils) in the top 2 feet, cap a flaggy buff sandstone, below the First Grit. Some distance downstream, a green sandstone is revealed.

A few isolated exposures of fine grained, flaggy, sandstone occur in a feature to the north, with 15 feet of sandstone (No.143) outcropping in the stream running into East Rake Hush. Of the overlying beds nothing is seen until the stream running between East and West Rake Hushes. Above the sill, a 9 inches green sandstone (No.153) is followed by grey fossiliferous shales with thin mudstones. The marine band is succeeded upstream by at least 10 feet of limonite stained, grey, sandy shales, and some flaggy sandstones below the First Grit; a slightly thicker sequence than in Horden Sike to the south.

North of the Lodgesike - Manorgill Vein, the Grindstone Sill feature continues around Carrs Hill and north westwards up the western flanks of Great Eggles Hope, for over a mile before swinging north eastwards to White Swangs and the head of the valley. There are no exposures until we reach Lodgegill Sike, where a valuable section is available. The Grindstone Sill is revealed as 20 feet of fine grained, flaggy buff sandstone, capped by 2 feet of famped limestone or calcareous sandstone, and 4 feet to 5 feet of fossiliferous grey shale below the First Grit. Unless this marine shale is a distinct, lower horizon than that seen before, the green sandstone is here absent through non-deposition. Alternatively, the marine band could be a lower one, hitherto undetected, with the green sandstone having been removed by a transgressive First Grit. The famped limestone above the sill, proves to be the first exposure of a fairly widespread horizon at the top of the sill. North of the Sike, exposure is poor, and sporadic, 6 feet being the most extensive outcrop. In the streams in Great Eggles/Head, a flaggy sandstone is exposed, and above the Grindstone Sill, a thin, tough, fine grained pinkisl quartzite similar (except in colour) to that in Hudeshope Grains.

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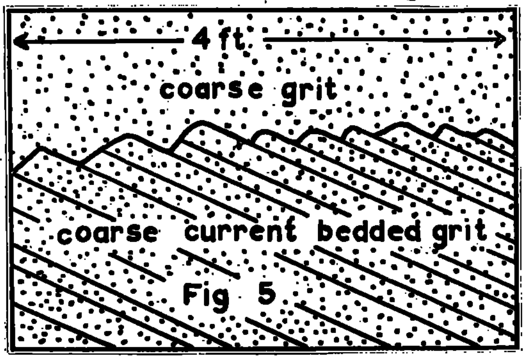
Along the eastern slopes of Great Eggles Hope the Grindstone Sill - First Grit feature follows a slightly sinuous course to the south east, with the First Grit forming an independant feature for a distance of 200 yards to the north of High Grey Stones, and south south eastwards from below the curricks south of Harnisha Hill (968317). Exposures are very poor.

The Grindstone Sill is downthrown 98 feet to the south by the Little Eggleshope Vein (Dunham, 1948, p.307), but a curved fault brings it up once more to form a convex feature south west of the Little Eggleshope Mine reservoirs. After running less than ¼ of a mile to the south and south east, the feature is interrupted by the Flake Brig Vein, which throws it down to the south. Here, at the head of Dusty Gill, soft grey and yellow shales are followed by 4 feet of black shales, passing up into 3 feet 6 inches of soft, fossiliferous, grey and yellow shales (No.169), a 3-inches coal, and 8 feet of shales, sandy and micaceous at the top, below the First Grit. The Grindstone Sill is not exposed, but a prominent feature runs from the fault around Middle End, petering out as it enters Little Eggles Hope. The top of the sill is conjectural, but the First Grit forms an intermittent feature giving some indication. The only exposure of the sill in this feature, is of some fine grained, micaceous sandstone 40 yards north east of East Rake Vein, which lets the sill down 10 feet to the north west. The fossil shale ?fossiliferous in Dusty Gill is probably equivalent to the marine band seen in the western flanks of Great Eggles Hope and Eggleston Burn, in which case the coal is a new development.

Near the confluence of Little Eggleshope and Candlesieve ? Sike, the Grindstone Sill is seen in both streams as a flaggy or shaly sandstone, forming a "fish-tailed" outcrop. In Little Eggleshope Beck, some calcareous shale grading up into 15 inches limestone, shaly and muddy at the base, and fossiliferous at the top, occurs above an apparently thin coarse grit, which may or may not be the top of the Grindstone Sill (a gap of a few feet occurs between this grit and the shaly sandstone below). Above, some black shales are seen, but the base of the First Grit and any intervening beds are hidden. This limestone may be equivalent to that on top of the sill in Lodgegill Sike, with a thin shale parting below, or it may possibly be equivalent to the later marine shales. In the right bank of the beck near Little Eggleshope Mine (989309), some coarse grit representing the Grindstone Sill crops out over some black shale with ironstone nodules and plant remains. In a stream running eastwards into the beck from the reservoirs, the top of the Grindstone Sill is exposed as a soft, fine-grained, grey, micaceous sandstone with plants, capped by at least 4 feet of soft grey shales, below the First Grit. On the left bank, some poor sandstone exposures occur, and near the lead mine, a feature swings east south east for 700 yards until interrupted by the Flake Brig Vein down-throwing to the south.

Immediately north of the East Rake Vein, where it crosses Little Eggleshope Beck, the First Grit is seen to overlie 3 inches to 9 inches of sandy grey shales above a grey fairly coarse grained grit, possibly the top of the Grindstone Sill. If this is the case, the First Grit transgression has become more active. 30 yards north of the vein, an interesting section presents itself in the right bank.



The sketch opposite is roughly to scale. The current bedded grit has a definite upper edge, as shown, but there is little, if any, difference in the other lithological characters of this and the overlying, massive grit. There are various possible explanations. It may represent a disconformity within a grit (First Grit), but this is highly unlikely. To present a distinct upper edge like this, the flags must have been fairly well consolidated to preserve such sharp edges, prior to the deposition of the upper grit. This would require a fair interval of time, and surely such a disconformity would be seen elsewhere in the area. This is not so. The second explanation is that the current bedded grit represents the Grindstone Sill, with the upper grit the transgressive base of the First Grit, the transgression having removed all overlying beds, and part of the sill itself. Objections might be raised concerning the nature of the grit, but the Grindstone Sill is seen to be a coarse grit upstream, and coarse grit lenses occur in the sill on Bollihope Carrs to the north. Downstream a few yards, a flaggy, medium to coarse grit with carbonaceous plant remains crops out in the stream, and grades down into a medium grained sandstone or grit, which is current bedded. It does seem best to regard this as the First Grit/Grindstone Sill contact, the latter being coarse grained and current bedded at the top in this locality, and with the First Grit transgression becoming more active, cutting down into the Grindstone Sill itself.

South of the vein, the upthrown sill is exposed in the stream bed and banks, with a few feet of grey shale with plants above it, 200 yards - downstream. Exposures are poor however, the best only revealing 9 feet of medium grained flaggy buff sandstone. The beds swing up slightly from the valley, to a height of 1,400 feet O.D. east of Middle End Farm (987288), and then maintain this elevation fairly constantly in a feature running south in a slightly sinuous course to the north west - south east fault from Lodge Sike. The feature, combining the Grindstone Sill and First Grit has an apron of thick drift below it, which in places partly masks it but its boldness is seen at Brown Dodd (see plate 9 ,p.245). There are no exposures along this feature, so that the top of the sill is conjectural. The base of the sill is taken at the base of the feature. Beyond the fault, the downthrown feature swings south westwards around Knotts, where it is once more downthrown to the south by the east north east fault running through Knotts.

<u>South Grain - Ayhope Becks, Sharnberry Gill - Euden Beck, and Spurlswood Beck.</u> The Grindstone Sill first outcrops in South Grain Beck near the old Lead Mines (022322), where the top of the sill is exposed in the stream bed as a micro-current bedded, fine grained, shaly sandstone. Above, 6 or 7 feet of shales with a thin sandstone occur. The First Grit occurs

anything up to 10 feet or so above. No sign of a limestone on top of the sill, nor of a marine shale, is seen. Approximately 200 yards downstream, the sill is once more exposed, outcropping in both banks, and approaching a medium grained grit in places, with up to 25 feet of flaggy, current-bedded, medium grained, micaceous grit being exposed at one point in the right bank (024319). Further exposures occur where small tributaries cut into both sides of the valley. Nothing is seen of the overlying sub - First grit beds, but the top of the sandstone is marked in the left bank by a shale feature below the First Grit feature. On the less steep right bank, there are no corresponding features (possibly due to the effect of a general south easterly dip), and the top of the sill is conjectural until we reach the quarry west of The Loop (033314). From here, a line of springs serves to mark the top of the sandstone, while a feature delineates the base of the First Grit. Why?

At The Loop, a north north west running fault (the Black Hill Fault) lets down the sill to the east approximately 20 feet, with the base of the sill outcropping 100 yards downstream, dipping due west at 3° into the fault. 20 feet to 25 feet of flaggy, micaceous, fine grained sandstone dipping south west at 8° are seen in a small stream in the south bank (035314), with some loose famped limestone suggesting that the limestone above the sill may be present. The sill can thus be mapped accurately for upwards of half ½ a mile east of the fault, but nothing of the overlying beds is seen below the First Grit feature, which runs practically the length of the south Grain Beck and Ayhope Beck valleys, within the area mapped. In the northern banks, features mark the base and top of the sandstone eastwards, almost to North Grain Beck. Some springs rise in the shale feature below the First Grit feature.

In North Grain Beck, 5 feet to 6 feet of fine grained sandstone with some thin shales and a 4-feet tough sandstone above, crop out below the First Grit in a small tributary stream (046322). The shales appear to be a shale parting, but exposure is poor. On the east bank of the beck, a feature, which probably includes the Grindstone Sill together with underlying and overlying beds, runs around into Ayhope Beck below the bold First Grit feature, with springs rising in the shales below the grit. A tongue of drift extends up the beck, below this feature. In Ayhope Beck it rises up over the Grindstone Sill as far as the base of the First Grit feature, approximately 300 yards east of the Meeting of the Grains. In a tributary in the north bank (059316) 35 feet of fine grained, flaggy, micaceous, buff sandstone (No.292) is exposed, but the base is not seen. This is the greatest thickness so far recorded in the Grindstone Sill. It is of some interest to note in passing that the overlying First Grit reaches the unusual thickness (for this area) of 70 feet in this stream. In Hawke Gill Sike, 2 feet of micaceous, fine to medium grained sandstone outcrops some distance below the First Grit, otherwise the sill is concealed beneath drift.

In the southern bank of Ayhope Beck, our only glimpse of the sandstone is in a tributary stream (051313), where some flaggy, fine grained, micaceous sandstone is seen. To the east, the drift rises up the valley side to skirt the First Grit feature. Apart from the exposure near the lead mines in South Grain Beck, beds succeeding the sill do not crop out.

In Sharnberry Gill, the top of the Grindstone Sill, very poorly exposed, crosses the beck near Sharnberry Lead Mine (012308). Above, it grades up into 6 feet limonite stained, grey, micaceous mudstone overlain by 1 feet of grey and orange, soft fire clay, and 15 inches to 6 feet of black shale below the transgressive base of the First Grit (plate 11 ,p. 283). In some old quarries just over 400 yards downstream in the left bank, up to 30 feet of fine to coarse grained sandstone (No.194c and d.), with calcareous cement in places, are exposed, capped by only 5 feet 6 inches of soft, fine grained grey shale beneath the grit. Thence downstream, intermittent more-or-less extensive sandstone exposures allow accurate mapping of the Grindstone Sill along the northern bank, down to Euden Beck.

In the southern bank, the sill can be accurately traced to a point opposite the quarries, but eastwards, its position is interpretted in relation to the better exposed First Grit. 500 yards downstream however, exposure improves considerably, and a good section from near the top of the First Grit almost to the Upper Felltop Limestone presents itself. The Grindstone Sill consists of 25 feet to 30 feet of flaggy, micaceous sandstones with a 6 feet capping of fine grained sandstone with lenticles of fine grained, dark grey limestone. These lenticles grade laterally into sandy limestone and calcareous sandstone. Above the limestone, 15 feet to 20 feet of shales and sandstones occur below the First Grit which has lifted slightly since last seen in the quarries to the west.

Good exposure facilitates accurate mapping downstream for 400 yards, after which it is once more drawn in relation to the overlying grit, until we reach a feature on the spur of land between Sharnberry Gill and Cloudlam Beck, which has been taken as marking the Grindstone Sill.

In the left bank of the gill, 500 yards north of Redgate Shields, 10 - 12 feet of flaggy and shaly, fine to medium grained, microcurrent - bedded sandstone, capped by a 22 inches sandy, micaceous, limonite-stained, grey limestone, occurs over sandy, grey shale. Traced upstream, the sandstone thickens slightly to 14 feet separated from the overlying First Grit by only 2 feet of sandy, micaceous, grey shale. The limestone is not seen here, but the sandstone is obviously the Grindstone Sill, which has thinned to the south from upper Sharnberry. South and then south eastwards, a distinct feature runs into Euden Beck along the left bank almost as far as a small stream where the sill crops out. A total of 20 feet of flaggy sandstone, dipping south east at 3^{o} to 4^{o} is exposed. On top of the sandstone an 18 inches fossiliferous, partially famped, grey limestone occurs, followed by 8 feet of sandy shale passing up into a shaly, flaggy sandstone. A gap of a few feet occurs before the First Grit is seen. To the west of the stream, the beds descend sharply from 900 feet to 800 feet O.D. This may be due to the continuation of the fault encountered in South Grain Beck (p. 208), but no sign of faulting is seen in teh southern bank. The Second Grit comes in along this line (see p. 293) and one would expect the underlying beds to downwarp beneath this grit, as in fact they can be seen to do in the southern bank (see plate 13 ,p. 291). The fault referred to undoubtedly affects the Third and Fourth Grits to the north, and probably affects the First Grit (with the Second Grit coming in to the east) on the north bank. An east - west fault has been mapped to the west in Euden Beck, downthrowing south. These two faults probably meet just a few yards upstream from the small tributary revealing the Grindstone Sill, enclosing an uplifted block of country on the northern bank. The north north west fault running from South Grain Beck (which one might expect to develop along the line of an incoming grit in strata subjected to stress) is relieved by this east - west fault, and south of the beck is replaced by a simple, unfaulted, downfold.

East of the small stream, a prominent feature housing both the Grindstone Sill and the First Grit, runs the length of Euden Beck, skirted by thick drift (which rises over the feature at the stream). The only exposure in this feature is in another small stream 1,300 yards east, where 25 feet to 30 feet of fine grained, micaceous sandstone represent the Grindstone Sill. The limestone is not seen, nor are any other beds below the First Grit. The feature descends slowly from 800 feet O.D. in the west, to approximately 720 feet O.D. in the east.

The Grindstone Sill has been traced down the right bank of Sharnberry Gill as far as Cloudlam Beck, where a feature has been taken as the sill. This feature runs a short distance along the northern banks of Cloudlam Beck, with a correspondingly short-lived feature on the southern bank. Drift obscures the feature upstream, and along the southern bank of Euden Beck until we reach Acton Beck. The sandstone itself is not seen until we reach a poor sandstone exposure in Morton Shields Beck 500 yards upstream from its confluence with Cloudlam Beck. Above it, some shales and sandstone crop out in the stream. The sill has risen from a height of approximately 930 feet O.D. near Redgate Shields, to about, 1,025 feet in Morton Shields Beck. In Cloudlam Beck, the top of the sill outcrops a few yards above the mouth of Cloudlam Rake (017289), and the sandstone (No.201) is fairly well exposed downstream for over 400 yards. A total of 15 feet to 20 feet of fine grained, flaggy, mottled sandstone crops out, the top few feet becoming medium grained and containing plant remains. Apart from an exposure of fine grained, olive coloured sandstone (which becomes flaggy, medium grained and micaceous downwards) almost immediately below the First Grit on the Union and R.D. Boundary, nothing is seen of the overlying beds. Whether this is the green sandstone met with elsewhere is not clear.

In Acton Beck, 15 feet of flaggy, micaceous sandstone is exposed, with 10 feet of grey shale and shaly mudstone above it, followed by the First Grit. No limestone capping is seen, no marine shale, nor a green sandstone. Downstream dips of 5° west and 3° to 4° east are recorded, the latter representing the general dip of the strata, bringing the Grindstone Sill in the southern bank down until it crosses the 900 feet contour as it swings around into Euden Beck. On the northern bank, the sill feature peters out when it turns northwards into Euden Beck.

Eastwards down Euden Beck, nothing is seen in the southern bank until we reach some old quarries 800 yards from the mouth of Acton Beck. In these quarries, which run almost continuously for a distance of 300 yards, the First Grit rests directly on the Grindstone Sill in the west, but rises to the east so that the sill is succeeded by 10 to 15 feet of unexposed strata below the base of the grit. 14 feet of fine to medium grained flaggy sandstone are seen, capped by 2 feet of sandy, micaceous, grey limestone which grades laterally into fine grained sandstone. Intermittent exposures (the ground is afforested) allow one to confidently link up the quarry exposures with those of King's

Crag 500 yards downstream, where the Grindstone Sill has dipped down below the 800 feet contour. In King's Crag, the sill consists of 17 feet of fine to medium grained, flaggy highly micaceous sandstone (No.230) with shale partings, and becoming very shaly towards the base. It is capped by a sandy grey limestone from 2 feet 6 inches to 3 feet thick (No.230). None of the overlying beds are exposed in the steep slopes, though the base of the overlying grit is marked by a feature. The sandstone here apparently dips almost due south at 5°. This may be due to slight landslip however, as the sill continues to descend downstream (east north east) to well below the 700 feet contour in Birch Plantation, where a greenish, micaceous, flaggy sandstone outcrops, linked with King's Crag by a feature. That a strong southerly component is present in the dip, is nevertheless proved by comparing the elevation of the sill on the northern and southern banks of the beck.

Apart from a poor exposure of shaly sandstone in a small stream in Birch Plantation (063298), nothing further is seen of the drift covered Grindstone Sill until we reach Spurlswood Beck. Here, immediately south of the east north east fault, which persists thus far from Stotley and Knotts, the downthrown sandstone is exposed in the stream bed dipping west at 30° towards the fault, and south a few yards upstream. 10 feet of fine grained, buff sandstone crop out capped by a 14 inches famped limestone. The sandstone (No.228a) floors the beck for 600 yards upstream, with the dip gradually swinging around to south of east at 3° (061288). At this point it is succeeding by 2 feet to 3 feet of sandy grey shale and some green, very micaceous flaggy sandstone (No.228b), with a gap of 4 feet below the base of the First Grit. No limestone is seen, so that the medium grained flaggy, greenish sandstone below the shale, which is taken as the top of the Grindstone Sill, may not in fact be so, but a thin sandstone occurring somewhere close above the sill.

The Eggleston Area. - Nothing is seen of the Grindstone Sill and succeeded beds in the Blackton Beck area, except for some baked shales below the First Grit immediately south of the fault through Knotts, a thick drift cover obscuring all the relevant solid geology.

A stream running into Redmire Gill (which occupies a glacial overflow channel) reveals a useful section beneath the First Grit. At the base, a 16 inches ganister is capped by a 1 foot siliceous green siltstone (No.289a) similar to that seen below the First Grit at the head of Bleagill Sike (p. 200). After an 8 feet gap, 20 feet to 25 feet of grey-green, silty shales are succeeded by 6 feet of interbedded green micaceous shales and fine grained green sandstones (No.289) and 8 feet to 10 feet of soft, grey, micaceous shales below the grit. The green sandstones and shales can be compared to the green sandstone seen elsewhere below the grit. To the east north east, the grit feature rises up the northern valley side and the grit can be seen to dip west of north at 35° to 37°. The Grindstone Sill probably occurs in the valley side here, but is not exposed. A west north west fault runs down the gill, bringing the Second Grit on the south below the First Grit on the north.

South of the fault, near Durham Woods Tower, a very prominent feature, capped by the First Grit, lies within four bounding faults, the Redmire Gill Fault on the north, the Southern Eggleston Fault on the south (running down the Adder's Gill -

Goose Tarn Beck overflow), and two north north west faults down-throwing to the east, on the western and eastern sides. The Grindstone Sill is exposed above a mound of drift in Goose Tarn Beck in the south eastern corner of the fault block where 15 feet of fine to medium grained, current bedded grit is seen. Immediately east of this, the downthrown sill is coarser grained, but shaly towards the top, and dips east of north at 30°. East of the Woodlands road, 4 feet of creamy, flaggy, micaceous, ganisteroid sandstone outcrops in a small stream, dipping west of north at 30°. North of the road (which swings east - west here) some old quarries reveal a 6 feet ganister dipping north at 30° and succeeded by 10 feet to 15 feet of grey shales with some fossil fragments, possibly representing the marine shales seen in Hudes Hope and elsewhere. The Primary Surveyors mapped a limestone above the quarry, and while the limestone is not seen in situ now, some loose pieces of thin (2 inches) muddy, crinoidal limestone were found.

In Pallet Crag Gill, below Birch Cottage (026236) a good section is revealed below the First Grit (see fig. 3c ,p. 74). The 2 inches to 4 inches sandy grey limestone (No.294a) is probably the same as that mapped in the old quarries to the west by the Primary Surveyors, though they didn't continue it this far. The underlying green sandstones and shales are similar to those seen in Redmire Gill. Below these, at least 60 feet of shales and sandstones are seen, with no sign of the Grindstone Sill, so that the succession between the green sandstone and the Grindstone Sill is very much thicker than to the north west.

70 yards upstream from the Pallet Crag Gill/Goose Tarn Beck confluence, 12 feet of coarse grit belonging to the Grindstone

Sill, dip north west at 50° into the Southern Eggleston Fault, which crosses Pallet Crag Gill near here. The grit is lost sight of for 140 yards downstream, but reappears as 11 feet of current-bedded, medium to coarse grained grit (No.329) dipping north east at 20°. Current bedding directions suggest a southerly source. Nothing is seen of it in its right bank, but on the plateau top (this forms part of a downfaulted, dissected plateau), 70 to 80 yards west of Howlsworth (022232), 9 feet to 10 feet of coarse, micaceous buff grit (No.295) crops out, dipping north. Some old quarries 50 yards further west show 4 feet of fine to medium grained, flaggy grit at a lower level (10 feet approximately) but obviously forming part of the same horizon. Further west again, beyond the Woodlands road, an old quarry in the northern bank of a Third overflow (which might conveniently be called the Folly Head Overflow) reveals 20 feet to 25 feet of medium grained buff grit with pockets of soft carbonaceous shale and coal streaks (No.293). A feature runs west north west from the quarry, but no grit is exposed through the drift cover. A small fault has been mapped roughly following the course of the Folly Head Overflow)so that the three overflows are fault controlled), in a west north west - east south east direction. It has already been mentioned as downthrowing the Fossil Sandstone to the south in Pallet Crag Gill, the sandstone dipping south east at 8° into the fault. It brings down the coarse grit seen upstream in Pallet Crag, to outcrop on Scroggs in the left bank of the stream. Up to 17 feet of fine to coarse grained, current bedded (south easterly source) grit occur in crag exposures.

It is in the area south of the Folly Head Overflow - Pallet

Plate 7.

A. The Grindstone Sill, Pallet Crag area. On the left, the sill has been quarried in Howegill Quarries where the horizon is of normal lithology. In Pallet Crag, to the right, the sill is represented by a coarse grit.

B. A closer view of Pallet Crag. The sill is here about forty feet thick. Numerous large joint-blocks of grit skirt the crag.

Crag Gill that the more interesting and informative exposures occur. At Pallet Crag (plate 7B ,p. 218) 38 feet of massive, medium to coarse grained grit (No.301) dip south east at 15°, obviously the same grit as that on Scroggs, upstream in Pallet Crag Gill, and west of Howlsworth, but better exposed. 130 yards upstream in the overflow, and for a distance of over 400 yards, old quarries reveal up to 15 feet of fine grained, flaggy, current bedded sandstone (No.296) with some plant remains and lenses of sandstone with a liberal calcite cement. The beds dip south south east at 7°. There is also one exposure of coarse grit (023228). The Survey mapped a fault between these quarries and Pallet Crag, which on the face of it seems perfectly reasonable, the two beds being lithologically very different. In Howegill Quarries to the south of Pallet Crag, situated in a deep, practically dry channel (see plate 7A ,p. 218 , and p. 427) 30 feet to 35 feet of flaggy, fine to medium grained, cream sandstone (No.299 and 300), calcareous (No.300a) in places, and with washout phenomena within it, can be seen (plate. 8 ,p. 219). This sandstone is undoubtedly the same one as that seen in the quarries in Folly Head overflow, south of the fault. This sandstone can be traced into Howe Gill, another dry channel (p. 427). If one admits the existence of the fault West of Pallet Crag, one must similarly separate the Pallet Crag and Scroggs grit from the sandstone in Howegill Quarries - this necessitates a very sinuous fault, which, though not impossible, is highly unlikely, and for which there is no structural evidence. Also it should be borne in mind that the grit on Scroggs varies from fine to coarse grained; that a coarse grit crops out in the midst of the sandstones in the old quarries west of Pallet Crag;

Plate 8.

Close-up of the Grindstone Sill in Howegill Quarries, displaying washout phenomena. The sill is about thirty eight feet thick in this locality.

and that washout phenomena occur within the sandstones in Howegill Quarries, accompanied in one case, by hollow ironstones nodules (No.300). We are left then, with one of two explanations:

1) That the grits are merely lenses within the Grindstone Sill (identified relative to the Fossil Sandstone below), as occurs in Bollihope Carrs (Dunham 1948, p. 42), or

2) That they are lenses of a Transgressive First Grits

The washout phenomena are of some interest. At the western end of Howegill Quarries, a washout plane occurs 7 feet from the top of the exposed sandstone. Up to 6 inches of grey silty shales occur, filling in a small hollow in the underlying sandstone. The shales are current bedded, with a north westerly source direction, which tallies with the current bedding of the underlying sandstone. Some shale chips are incorporated in the overlying sandstone. No obvious grain size difference can be detected in the sandstones above and below the washout plane, but in the large, central quarry (see plate 8 ,p. 219) the sandstone above does tend to be slightly coarser, becoming medium grained in places. Current bedding in the sandstone at a higher level to the west (no washout seen) is also to the south east. In the coarse grits, current bedding, where measured (Scroggs, Pallet Crag Gill, and old quarry north of Pallet Crag House) varies from north to north west, suggesting a southerly to south easterly source.

It seems unlikely (though not impossible) that between the Birch Cottage exposures and Pallet Crag, the First Grit has cut down through approximately 90 feet to the Grindstone Sill, and in places removed this also. Lenses of coarse grit does seem the better explanation, and this has been adopted.

Above the quarries north west of Pallet Crag, a large, mound - like feature exists, with some very large, loose blocks of coarse grit identical with that of Pallet Crag scattered over it, suggesting that the grit "lens" rides over the sandstone to the north west. A dip-slope feature at the western end, dipping east south east at 4^{o} may represent the dip off the top of the petering out lens. West of the Howegill Quarries, flaggy sandstones are exposed in a stream channel becoming rapidly shallower to the west, and at a distance of 180 yards west some massive, coarse grit crops out in a small, knoll-like feature. Further "lens" features occur to the west, and each contains old quarries which worked the coarse grit forming them. Up to 9 feet of coarse grit is exposed, dipping (and forming a perfect dip slope north of Pallet Crag House) east south east at 7^{o}, and 15 feet - 20 feet of coarse grit occurs in Roger Moor Quarry to the south. Mounds of drift to the west have made it impossible to map the boundaries of the Grindstone Sill accurately but some flaggy exposures near Windy Hill (017223) serve as useful checks until we reach the feature running west from Roger Moor (023220). East of Roger Moor, and running north north west to meet the Folly Head Overflow, a fault downthrowing east and generally flanking the grit lens features to the west, has been mapped. It was not invoked to explain the termination of these lenses, as no such explanation is necessary, but is mapped on the evidence occurring at the head of Howe Gill. An old quarry at Moss Close (025218) reveals some fine grained, flaggy, cream sandstone; these flags are also exposed in the opposite bank of the gill further west. In the southern bank 100 yards south west of the latter exposure, silty grey shales crop out at the same level.

30 to 40 yards south, approximately 15 feet or so higher, an old quarry exposes 10 feet of flaggy, medium grained sandstone (shaly towards the base), obviously the upthrown Grindstone Sill, which forms a semicircular feature running around to Baxtongill Quarry. The Survey mapped this fault also, presumably on the same evidence, and the added incentive of explaining the disposition of the coarse grit outcrops to the north.

Some distance below the Grindstone Sill feature mentioned above, the Fossil Sandstone is exposed in the stream below High Shipley near the 900 feet contour and running southwards until downthrown by a north west - south east fault. This fault brings down the Grindstone Sill below the 900 feet contour in Shipley Banks Wood, and a series of old quarries have worked it to reveal 25 feet of fine to medium grained, flaggy sandstone, current-bedded in places, and containing a calcite cement in bands and pockets. The sandstone dips west at 3° while the current bedding suggests a north easterly source.

To the east of Howegill Plantation, some old quarries (033220) reveal 12 feet of medium to very coarse grained grits (No.304) dipping north east at 6° to 12°, while to the west, of the quarries, some shaly and flaggy medium grained, buff sandstone is exposed in a shallow gutter at the roadside, at approximately the same level as the grit in the quarries.

With regard to the distribution of these lenses, they might represent the remnants of a continuous sheet whose base was irregular, but, with the exception of an intermittent dry channel at Roger Moor Quarry which may link up with the Howegill Quarries channel, it is difficult to see what has effected the erosion. It seems more likely that the distribution is an original feature, possibly with two channels following a roughly north north west-south south east and a north west - south east source, one extending from Bracken Heads (015234) to Roger Moor, the other from Howlsworth to the quarries east of Howegill Plantation. Alternatively they may represent sand banks, although the Pallet Crag grit obviously occupies a deep channel of some sort.

Lunedale. - The area called "Millstone Grits" on Romaldkirk Moor is aptly named, for the ridge, overlooking Lunedale to the north, is capped by the First Grit. To the north, below the grit, a feature runs in a south west - north east direction around Harker Hill to Swarthy Top. Within the area surveyed nothing is exposed through the thick, matted heather, until the feature swings around to a west north west - east south east direction beyond Swarthy Top, to the West Pasture Road Vein. Some old quarries (961220) reveal fine grained, cream coloured flags. Below this feature, the more prominent Parson's Rigg feature is formed by the Low Grindstone, or Hipple Sill, so that the upper feature must belong to the Grindstone Sill. As we approach the vein to the east, the feature swings round in a sub-parallel direction and appears to die out below the First Grit, either due to transgression, or to the influence of the fault. No contact between the grit and the underlying beds is seen.

PALAEONTOLOGY.

The coral - brachiopod fauna of the Great Limestone is characterized by the dominance of Dibunophyllum bipartitum varieties, including the bipartitum, craigianum, and koninoki types with the latter being most abundant, as in the Four Fathom Limestone. Hill (1938) has indicated the dominance of this type in her Coral Zone 3. One difference between the dibunophyllids of these two limestones, is that the koninoki varieties tend to develop dilated septa near the cardinal fossula, within the tabularium, in the Great Limestone. Aulophyllum fungites Fleming mut.pachyendothecum also displays septal dilation, in a more marked degree than in the Four Fathom Limestone specimens, up to half the septa being affected. G.A.L. Johnson noted this phenomena on in Weardale and Northumberland, but the position was reversed in that the specimens showing marked septal dilation occur in the Four Fathom Limestone. The difference can have no zonal significance therefore and must merely be the result of some environmental conditions.

An important member of the coral fauna is Lonsdaleia floriformis tw laticlavia Smith, which is restricted to the Great Limestone in Northern England. Johnson found it in reef coral faunas near the base of the limestone.

The brachiopod fauna is varied, but Productus (Gigantoproductus) latissimus J. Sowerby and Dielasma spp. are probably the most common forms. Of particular interest is the occurrence of P. (Gigantoproductus) giganteus group Martin sp. from Bale's Hush, Flushiemere. It has been found in the Great Limestone of Weardale, but does not usually occur above the Five Yard Limestone. It has not been recorded above the Great

Limestone to the author's knowledge. Sinuatella sinuata (de Koninck) occurs rarely in the Great Limestone, and is not met with again until the Upper Felltop Limestone, where it is the dominant member of the fauna.

The Great Limestone microfauna contains some useful forms. The most important of these is probably the occurrence of "Algae α" Johnson in thin sections No.26, and 205. G.A.L. Johnson tentatively refers this to phyllum Algae, and it has already been pointed out (p.63-64) that both he and Short (1954) record its maximum occurrence in the Great Limestone with restricted occurrences in the Four Fathom and Five Yard Limestone. The abundant presence of the organism in slide No.26 was instrumental in establishing the true identity of the limestone, which is a faulted inlier (see p. 128). Johnson regards the organism as being almost restricted to the top of the "Upper Main Post" of the Great Limestone (1953,p.45). The location of this specimen is however, no more than 20 feet from the base of the limestone. The quarry from which the specimen was obtained reveals 14 feet of limestone but the base is not exposed. The total thickness cannot be much more, as no limestone is seen in the banks of the Lune, only 30 yards away, the top of which is only a few feet below the bottom of the quarry.

This thin section (No.26) also revealed Girvanella s.s. sp. a series of bifurcating tubes, not the 'Girvanella' nodules which are abundant in the lower limestones of Northumberland and consist of Girvanella tubules, foraminifera, Novicularia, and limonite. Johnson referred these nodules to the genus Osagia. He records G.oxfordensis from the upper part of the middle section of the Main (Great) Limestone, and the lower Tumbler

Beds in Northumberland, but <u>Girvanella spp.</u> occur in every limestone from the Little Limestone, well down into the Middle Limestone Group. The presence of both these forms in No.26, leaves little doubt as to its identity. In addition a fragment of a <u>Dibunophyllum</u> with dilated septa was found (No.26).

<u>Archaediscus karreri s.s.</u> Brady occurs in the Great Limestone (No.68) and the Little Limestone (Nos. 171, 317), while <u>A. karreri Brady var. β</u> Short was located in the Crag Limestone (No.67), and the Lower Felltop Limestone (No.322).

FAUNA OF THE UPPER LIMESTONE GROUP.

The Great Limestone.

"Algae α " Johnson.
Calcisphaera fimbriata.
------------ "μ" Johnson.
Girvanella s.s.
Ammodiscus sp.
Archaedíscus karreri s.s. Brady.
-------------------- Brady var Short.
Climacammina antiqua Brady.
Cribrogenerina.
Cribrostomum bradyi Moller.
Endothyra crassa Brady.
--------- ornata Brady.
Valvulina (Tetrataxis) decurrens Brady.
--------- (----------) palaeotrochus Ehrenberg.
Aulophyllum fungites Fleming mut. pachyendotheoum Thomson.
Chaetetes septosa Fleming.
Dibunophyllum bipartitum bipartitum McCoy.
----------------------- craigianum Thomson.
----------------------- koninoki Edwards and Haime.
Diphyphyllum lateseptatum McCoy.
Koninckophyllum cf. echinatum Thomson.
Lonsdaleia floriformis laticlavia Smith.
Archaeocidaris (Ecinocrinus) sp.
Crinoid ossicles up to 6 mm. in diameter.
Bryozoa.
Cleiothyridina sp.
Composita ambigua (J. de C. Sowerby).
Dielasma hastata (Davies).
-------- cf. hastata (Davies).
-------- cf. sacculus (Martin).
-------- vesicularis (de Koninck).
Orthids.
Productus (Echinoconchus) elegans McCoy.
--------- (Eomarginifera) lobatus J. Sowerby.
--------- (Gigantoproductus) giganteus group Martin.
--------------------------- latissimus group J. Sowerby.
Sinuatella sinuata (de Koninck).
Spirifer bisulcatus group J. de C. Sowerby.
Spiriferellina cf. octiplicata J. Sowerby.

Shales below the Low Coal Sill.

Lingula mytiloides J. Sowerby.
Fish scales.

Shales above the High Coal Sill.

Fenestella spp.
Chonetes (Chonetes) cf. longispinus (Roemer).
------------------ cf. mosensis Demanet.
Productus (Linoproductus) cf. cora d'Orbigny.
---------- sp.

Schellwienella crenistria Phillips.
Nucula laevirostris Portlock.
Nuculana cf. attenuata Fleming.
--------- cf. sharmani Etheridge.
Bucaniopsis sp.
Euphemites urei (Fleming).
---------- sp.
Ptychomphalus sp.
Soleniscus cf. subglobosa Grabau.
Hyolithes sp.
Orthoconic nautiloid.
Orthotetid.
Productus(Buxtonia) sp.
--------- (Dictyoclostus) sp.
--------- (Productus) concinnus J. Sowerby.
--------- sp.
Schellwienella rotundata I. Thomas.
Bellerophon cf. pelops Hall.
Euphemites sp.

<u>The Little Limestone.</u>

Ammodiscus sp.
Archaediscus karreri s.s. Brady.
Endothyra bowmani Phillips.
--------- ornata Brady.
Orbiculoidea cf. nitida Phillips.

<u>Shales above the Little Limestone.</u>

Orbiculoidea sp.

<u>Shales below the Crag Limestone.</u>

Chonites sp.
Crurithyris amoena George.
----------- cf. unguiculus (J. de C. Sowerby).
----------- urei (Fleming).
----------- sp.
Productus (Buxtonia) scabriculus Martin.
---------- (Dictyoclostus) cf. sulcatus J. Sowerby.
--------- (Eomarginifera) setosus Phillips.
--------- (Productus) productus group Martin.
--------- sp.
Rhynchonella cf. trilatera de Koninck.
Spiriferina cf. acuta Martin.
Nucula cf. laevirostris Portlock.
------ oblonga McCoy.
------ sp.
Sanguinolites sp.

<u>The Crag Limestone.</u>

Archaediscus karreri Brady var β Short.
Cribrostomum bradyi Moller.
Endothyra ornata Brady.
--------- sp.

Ostracod.

Shales above the Crag Limestone.

Chonetes hardrensis Phillips.
--------- sp.
Crurithyris urei (Fleming).
Lingula cf. mytiloides J. Sowerby.
Productus (Echinoconchus) elegans McCoy.
cf. Punctospirifer kentuckyensis Shumard.
Rhynchonella cf. trilatera de Koninck.
Spirifer bisulcatus group J. de C. Sowerby.
-------- cf. triangularis Martin.
Cypricardiella cf. parallela Phillips.
Nucula sp.
Parallelodon cf. cancellatus Martin.
Naticopsis cf. trilatera de Koninck. ?
Porcellia sp.

The Knucton Shell Beds.

Athyris (Actinoconchus) lamellosa Leveille.
------- sp.
Chonetes (Chonetes) cf. dalmanianus de Koninck.
-------- hardrensis Phillips.
Productus (Dictyclostus) insculptus Muir-Wood.
---------- (?-----------) sp. - (shaped like Sinuatella, but too coarsely ribbed).
---------- (Echinoconchus) elegans McCoy.
---------- (Eomarginifera) longispinus J. Sowerby.
---------- (Productus) concinnus J. Sowerby.
---------- ------------ productus group Martin.
---------- ------------ sp.
---------- (Pustula) cf. punctatus Martin.
Spirifer bisulcatus group J. de C. Sowerby.
-------- cf. triangularis McCoy.
Edmondia cf. arcuata Phillips.
Solemiscus (Macrochilina) aff. globosa Grabau.
Euphemites cf. pelops (Hall).
Trilobite pygidia.

Shales between the Knucton Shell Beds.

Coleolus sp.

Siltstone below the Rookhope Shell Beds.

Lingula mytiloides J. Sowerby.
Productus sp.
Euphemits sp.

The Rookhope Shell Beds.

Crinoid ossicles.
Productus (Eomarginifera) cf. longispinus J. Sowerby.
------------------------- setosus Phillips.
---------- (Productus) carbonarius de Koninck.

Productus (Productus) concinnus J. Sowerby.
---------- sp.
Schizophoria resupinata (Martin).
------------- sp.
Aviculopecten cf. intermedius McCoy.
Edmondia cf. accipiens J. Sowerby.
Gastropodl
Bellerophontid.
Trilobite pygidium.

<u>Shales above the Rookhope Shell Beds.</u>

Fenestella sp.
Productus (Eomarginifera) cf. longispinus J. Sowerby.
---------- ------------- setosus Phillips.
---------- (Productus) cf. concinnus J. Sowerby.
---------- ---------- sp.
---------- sp.
Spirifer bisulcatus group J. de C. Sowerby.
Aviculopectem sp.
Cardiomorphia cf. limosa Fleming.
Nucula cf. aquilis J. Sowerby.
------ cf. laevirostris Portlock.
Trilobite pygidium.

<u>The Lower Felltop Limestone.</u>

Archaediscus karreri Brady var Short.
Cribrostomum bradyi Moller.
Endothyra bowmani Phillips.
---------- ornata Brady.
Valvulina (Tetrataxis) decurrens Brady.
Bryozoa.

<u>Shales above the Lower Felltop Limestone.</u>

Productus (Eomarginifers) sp.
Nuculana attenuata Fleming.

<u>Shales above the Transgression Beds Grit-the Coalcleugh Marine Band.</u>

Schizophoria sp.

<u>The Upper Felltop Limestone.</u>

Productus (Buxtonia) sp.
---------- (Dictyoclostus) cf. pinguis Muir Wood.
---------- (Eomarginifera) setosus Phillips.
-----------(Productus) sp.
---------- sp.
Rhynchonella cf. acuminata Phillips.
Schellwienella sp.
Schizophoria resupinata (Martin).
Sinuatella sinuata (de Koninck).
Spirifer bisulcatus group J. de C. Sowerby.
Aviculopecten sp.

Nucula sp.
Gastropod indet.
Bellerophontid indet.
Trilobite pygidia (non-mucronate).

Shales immediately above the Upper Felltop Limestone.

Hyolithes sp.

Shales between the Upper Felltop Limestone and the Grindstone Sill.

Cryptostomatous bryozoa.
Chonetes (Chonetes) cf. longispinus sinuatus Paeckelmann.
Productus (Dictyoclostus) pugilis J. Phillips.
--------- (Gigantoproductus) latissimus group J. Sowerby.
--------- (Linoproductus) cf. cora d'Orbigny.
--------- (Productus) carbonarius de Koninck.
--------- (---------) concinnus J. Sowerby.
--------- sp.
Aviculopecten sp.
Edmondia sp.
Pterinopecten sp.
Euphemites urei (Fleming).

Marine band below the First Grit.

Productus (Eomarginifera) setosus Phillips.
--------- (Linoproductus) cf. cora d'Orbigny.
--------- (Productus) carbonarius de Koninck.
--------- (---------) cf. concinnus J. Sowerby.
--------- sp.
Edmondia sp.
Nucula cf. aquilis J. Sowerby.
Orthoconic nautiloid.

PETROGRAPHIC NOTES.

The Great Limestone. (Nos. 6, 21, 26, 61, 68, 74, 78, 102, 235, 271, 310). A grey, fine to medium grained, crinoidal limestone. It is fossiliferous with bands of rolled corals and brachiopods. The limestone is muddy in places, particularly in the limestone members of the Tumbler Beds. It is abundantly microfossiliferous. The main body of the limestone generally consists of fine grained calcite, with larger fragments of calcitic shell material. Siderite ($N_e > 1.54$) is locally present, particularly in Coldberry Gutter, near the Lodgesike - Manorgill Vein, where it forms the bulk of the rock (No.61). No organic remains were seen in the latter section, which is also veined with quartz. Chert nodules are very rare in the Great Limestone of this area, but occur in the Tumbler Bed shales in Bales Hush, Flushiemere, and in the main body of the limestone at West Pasture Road Quarries in Lunedale (No.310). The latter shows a fine grained groundmass of silica with a large amount of brown carbonate material. Some originally calcitic organic remains (crinoid ossicles and one section of ribbed shell material) have been replaced by silica.

The Coal Sills. (Nos. 5, 7, 8, 17, 56, 57, 125, 256, 324) are a variable group of sandstones ranging from fine to coarse grained (0.1 - 1 mm diameter), and are generally compact. No.125 (the Low Coal Sill) is a medium grained (0.25 mm. diameter), tough, compact, quartzitic sandstone, of a grey-buff colour. It consists largely of rounded to subangular quartz grains, some of which show undulose extinction and slightly biaxial interference figures. Some of the grains have secondary mantles of silica. A few scattered grains of plagioclase felspar and of quartzite occur. Clay minerals occur in a few interstitial pockets, and some flakes of hydrobiotite are seen. Accessory zircons are present.

The Little Limestone. (Nos. 82, 83, 85, 171, 237, 264). A poorly exposed, variable, muddy or sandy grey limestone, fine to medium grained, and frequently crinoidal. In No.171, quartz grains form up to 30% of the section. They are angular and subangular, clear, and show undulose extinction and a slightly biaxial interference figure in some cases. A few grains of quartzite and some small, angular, and rounded zircons occur. It is microfossiliferous and contains fragments of organic calcite debris.

The Firestone Sill. (Nos. 65a, 146) is a medium to very coarse grained grit (.2 - 2mm. in diameter). In eastern Coldberry Gutter (No.65a) it is a medium grained cream grit with muscovite and hydrobiotite flakes. Quartz is the dominant constituent, frequently displaying strain shadows and some slightly biaxial interference figures. Quartzite and plagioclase felspar grains occur. Clay minerals are present interstitially, with varying amounts of black carbonaceous material. No.146 is coarser grained (up to 2 mm. diameter). Quartz is again the dominant constituent, but orthoclase felspar (largely decayed) forms up to 10 or 15% of the slide. The quartz shows undulose extinction and suitable sections reveal a slightly biaxial interference figure. There are some quartzite grains and flakes of hydrobiotite. Clay minerals are interstitial and form at least 5% of the section; numerous gaps in the slide probably represent clay minerals which have been removed in the process of grinding. Some rounded zircons and schorlite grains brown tourmaline also occur.

The Crag Limestone. (Nos. 63, 65, 67, 100, 172, 264c, 317). This limestone is normally a fine grained grey limestone with shell debris and crinoid remains. Small detrital quartz grains occur locally, forming up to 3% of No. 65. No microfossils were seen in the slides examined, apart from No. 317, in which some poorly preserved foraminifera occur. Siderite ($N_e > 1.54$) occurs in places, as in Hudeshope Beck (No. 172). In Coldberry Gutter, the limestone is more or less altered. Thus No. 100 is a highly altered limestone, with silica forming the bulk of the rock. The fine grained groundmass consists of quartz with siderite rhombs, not all of which are stained with iron oxide. Calcite, showing all stages of replacement by silica occurs; some crinoid ossicles and one bryozoa fragment are preserved in silica. Some crinoid ossicles are preserved in stained siderite. Traces of galena are present in the hand specimen. These various alterations are due to the mineralization processes giving rise to the adjacent Lodgesike - Manorgill Vein.

The Knucton Shell Beds. (Nos. 118a, 121). Fine grained, compact, grey or buff, limonite stained, frequently calcareous, shelly sandstones. Mica generally present in small quantities. No. 118a is variable, with the proportion of quartz grains to clay minerals varying from 3 to 1, and 1 to 3 respectively. The quartz grains are small and angular. Some outlines of organic debris now preserved in limonite occur. Flakes of hydrobiotite are fairly abundant. Some grains of zircon and tourmaline occur.

The Low Grit Sill. (Nos. 58, 87, 103, 106, 117, 119, 120, 123, 130a, 130b, 162, 163, 177, 188, 251, 253, 269, 280, 308, 311). Generally a medium to very coarse, pebbly grit (up to 1 mm. diameter), but locally fine grained (0.1 mm. diameter) (No.120). Clay minerals may form up to 20% of the rock. The quartz grains are angular to sub rounded and frequently display undulose extinction, and some a slightly biaxial interference figure. Inclusions in the grains vary in abundance, one grain showing a euhedral schorlite inclusion (No.106). Felspar, both plagioclase and orthoclase (generally largely decayed) are present, forming up to 2 or 3% (Nos.103, 106, 117) but sometimes as much as 8% of the rock (No.87). Quartzite is fairly plentiful, accounting for 15% of No.87. Muscovite and hydrobiotite flakes are generally present.

The High Grit Sill.(Nos. 91, 104, 105, 122, 124, 134, 139, 140, 251, 253, 269, 280) is lithologically very similar to the Low Grit Sill in all respects, including variability of grain size, and in mineral content.

The Sandstone above the High Grit Sill.(Nos 107, 108, 111, 129, 141a). A fine to medium grained sandstone (0.05 - 0.2 mm. in diameter), fairly compact. The clay mineral content varies, and may be as much as 25%, but is generally less in the specimens sectioned. Mica, usually muscovite, is generally present in small amounts. Limonite occurs in patches.

The Rookhope Shell Beds in Stobgreen Sike.(Nos. 281, 281a, 281b). The sectioned specimens are members of a chert - limestone - mudstone series regarded as local representatives of the Rookhope Shell Beds, which elsewhere in the area, consist of famped fossiliferous and apparently unfossiliferous limestones, and a fossil sandstone. Nos. 281 are specimens from a 10 inch chert band which is very fine grained, grey-buff in colour, with some black carbonaceous streaks. One of the slides consists of a mass of intimately associated pale brown and clear chalcedony (both showing fibrous radial aggregates), and calcite. Outlines of organic fragments, sponge spicules, are preserved in pale brown or clear chalcedony in some cases, calcite in others. In the second slide, no calcite occurs, the section consisting entirely of clear and pale brown chalcedony. Nos. 281 a, and b, are taken from a higher horizon consisting of a medium grained grey-buff limestone, stained with limonite in places (281b) which becomes dark grey, fine grained and siliceous, towards the base (281a). The former consists of finely crystalline calcite with no silica apart from some small pockets of pale brown isotropic silica, and three sections of sponge spicules formed of clear chalcedony. 281a is made up of intimately associated silica and calcite in a ratio of 4 : 1 (although calcite is locally more abundant). The calcite is generally more or less corroded. Some pellets of glauconite and small detrital quartz grains occur.

<u>The Lower Felltop Limestone.</u> (Nos. <u>178</u>, <u>260a</u>, <u>260b</u>, 260c, <u>314</u>, <u>322</u>, 322a). Best revealed in the Tees below Eggleston and in Lunedale, where it appears as a twin limestone, the upper limestone consisting of 4 feet of limestone with a thin shale parting (the basal part containing small pebbles (up to 3 mm.) of quartz, felspar, and some glauconite, the latter identified by X-ray analysis) and the lower limestone being made up of 3 feet 9 inches of limestone with two thin shale partings. The basal part of this lower limestone is very sandy, being in fact more in the nature of a calcareous sandstone. The two limestones are separated by 10 feet of shale in the Tees. The basal part of

the upper limestone has a characteristic lithology (Nos.260b, 322a) consisting of a fine-grained calcite matrix in which a few ill-defined micro-fossils occur (No.260b). The detrital material, which forms up to 50% of the rock, consists mainly (70%) of rounded quartz grains displaying undulose extinction and some of which have a slightly biaxial interference figure. Rounded grains of quartzite are next in importance (up to 15%) followed by microcline and orthoclase grains, which show all stages of replacement by calcite. In 322a, some of the felspar grains (microcline appears to be absent, although some grains are so corroded as to make the original composition very obscure) have what might be termed 'coronas' of clear fibrous calcite which in turn are surrounded by a concentration of iron pyrites. The felspar 'nucleus' is generally highly corroded but in one instance the felspar (?orthoclase) is fairly well preserved. Gilligan (1919, p.262) noted the frequent association of calcite and decomposed felspar and concluded that the original form of the felspar had been one of the less basic soda-lime group. One crinoid ossicle-shaped body consists of iron pyrites. No.260b contains one pebble of intergrown quartz crystals with two microcline crystals. Glauconite forms up to 10% of No.260b, occurring both in pellet form (with shrinkage cracks filled with calcite) and in smaller, interstitial patches. In 322a, the glauconite is largely confined to streaks of muddy material (up to 1.5 mm. wide) consisting of a very fine grained brownish matrix with abundant pellets of glauconite and small angular quartz grains. A large (.75 mm. in diameter) rounded grain of schorlite occurs in 322a, while two quartz grains contain euhedral crystals of tourmaline in 260b. Organic fragments of calcite and phosphatic material occur. The weathered surface is limonite stained.

The upper portion of the top limestone (260a, 322) is a normal fine grained grey limestone containing crinoid plates, microfossils and other organic debris in abundance.

The basal part of the lower limestone (260c, 314) is a coarse sandy grey limestone, with pockets of small quartz pebbles and some felspar. The foreign material is made up of two grades, fine grained angular quartz grains, and larger pebbles. Quartz is the dominant pebble constituent, with quartzite and felspar next. The latter is more or less replaced by calcite so that the original composition of the felspar cannot be determined. No cross hatching or lamellar twinning is seen in the larger grains, so the felspar is probably orthoclase. Some smaller plagioclase grains do occur, belonging to the andesine - labradorite range. No glauconite occurs.

The Transgression Beds Grit. (Nos. 9, 109, 110, 112, 128, 132 135, 142, 145, 148, 149, 156, 160, 179, 182, 250, 252, 255, 257, 282, 305, 312). A fine to very coarse grained grit, but generally of a medium or coarse grade (up to 1 mm. diameter). Degree of rounding is variable, but usually sub angular to sub rounded. Quartz forms an overwhelmingly dominant constituent, and frequently shows undulose extinction, and some grains possess a slightly biaxial interference figure. Quartzite grains form the next important constituent (apart from clay minerals) amounting to about 8 - 10% in some cases (No.142). Felspar is not conspicuous and is frequently absent, but may form up to 3% (No.110), generally consisting of corroded orthoclase.

Clay minerals vary in amount, but in the coarser grits may make up to 30% (110), on an average however, they form from 5 - 10% of the rock. Mica, mainly hydrobiotite, is fairly abundant locally amounting to 3 or 4% in some cases (No.112). A calcareous cement occurs in some places, (No.129) where it forms 7 - 10% of the rock. Accessories include zircon, tourmaline, apatite, and one rounded grain of what appears to be mica schist, (No.112).

<u>The Hipple Sill.</u> (Nos. <u>306</u>, <u>309</u>) a fine to coarse grained (.05 - 1 mm. diameter) sandstone or grit, generally flaggy. The quartz grains again show undulose extinction. Felspar forms up to 1% of the sectioned specimens, consisting of orthoclase mainly, but also some twinned plagioclase and microcline. Quartzite grains also occur, and mica (largely muscovite but some hydrobiotite) is fairly abundant. In both sectioned specimens there is a liberal carbonate cement (up to 60%) consisting of calcite only in No.309 but containing both calcite and stained siderite in No.306. The latter in hand specimen is limonite stained and brown in colour, while the former is a creamy - grey rock.

<u>The Upper Felltop Limestone.</u> (Nos. <u>151</u>, <u>234</u>). A fossiliferous grey, frequently haematite stained, generally sandy limestone, No.151 is particularly 'sandy' with detrital material forming as much as 30% of the slide. In hand specimen the rock has an 'oolitic' appearance caused by the detrital grains set in the creamy coloured weathered carbonate. It is limonite stained owing ~~due~~ to the oxidation of the carbonate which is probably siderate ($N_e > 1.54$). Irregular patches of clear calcite occur in the siderite where the latter has not succeeded

in replacing it. No.234, is even more 'sandy', 40% of the slide being composed of detrital material. 95% of the detrital material consists of angular (some sub-rounded) quartz grains. Felspar accounts for 1% of the slide, both orthoclase and plagioclase occurring, generally more or less replaced by calcite. Quartzite, muscovite and hydrobiotite also occur. The carbonate in this case is calcite. Some patches of limonite or haematite occur.

The Grindstone Sill. (Nos. 133, 143, 194c, 194d, 195, 201, 227, 230, 292, 293, 296, 298, 300a, 301, 303, 304). This varies from a fine to medium grained (0.04 - 0.2 mm) sandstone mainly, but locally becomes a coarse grit (.2 - 1.5 mm.). Quartz grains again show undulose extinction and slightly biaxial interference figures in some cases. Felspar content varies, but may form up to 12% in some cases (No.194d). Both orthoclase and plagioclase are present usually more or less corroded. Quartzite grains are sometimes present and in No.137 make up 2% of the slide. Mica is usually fairly abundant, with hydrobiotite and muscovite being present. Normally it accounts for 3 or 4% of the rock, but locally forms up to 30% (No.230 - 30% hydrobiotite). Clay mineral content varies up to 30%, (No.227, 143), but more normally forms between 5 and 15%. Locally the rock has a carbonate cement, as in 194c where 50 - 60% of the rock is calcite (felspar grains in this section are largely altered to calcite). Accessories include zircon, tourmaline and apatite.

Limestone capping of the Grindstone Sill. (No.230). Locally a limestone caps the sill, and it is fossiliferous in places. The sectioned specimen is a fine-grained, dark grey, crinoidal limestone consisting of fine-grained calcite with organic fragments of calcite, and some angular grains of quartz and quartzite.

The green sandstone below the First Millstone Grit. (Nos. 137, 153, 193, 228b, 289, 321, 332). A fine-grained, micaceous, green or greenish coloured sandstone, with some limonite staining. The green colouration is due to a groundmass of fine grained green chloritic aggregates with larger flakes of chlorite. Flakes of muscovite and hydrobiotite also are present. 50% of the rock consists of angular to rounded quartz grains from 0.04 - 0.25 mm in diameter. Some of these quartz grains show undulose extinction. Other detrital grains consist of quartzite and a few grains of plagioclase felspar. A few small rounded zircons occur in No.137.

CHAPTER 4.

THE "MILLSTONE GRIT" SERIES AND THE COAL MEASURES.

THE HISTORY OF RESEARCH ON THE ALSTON BLOCK.

The Upper Carboniferous is frequently divided into two contrasting lithological formations, the "Millstone Grit" (a shale-grit series usually lacking in workable coals), and the overlying Coal Measures. As early as 1867 G. Tate pointed out that this lithological classification could not be applied satisfactorily to the strata of Northumberland and Durham. To conform with the rest of the country, however, the strata between the highest marine limestone and the lowest workable coal in the Coal Measures, were placed in the "Millstone Grit".

The first contribution of any note to the Millstone Grit problem of this region was made by Westgarth Forster (1809, 1821, pp. 96, 163). He divided the strata into an upper "Coal Measure" group, and a lower "Lead Measure" group. Within the latter group he included the "Millstone Grit or Grey Millstone" a single bed of coarse grain, 27 feet thick. In Nall's 1883 revision of Forster's "Strata" however, the "Millstone Grit Series is enlarged to include the beds of the Healeyfield succession as revealed in the Healeyfield Lead Mine (1883, p. 91).

The primary surveyors took as the basement member of the series the first prominent grit above the Grindstone Sill, conforming with local tradition (Dunham, 1948, p. 45). The formation was divided into three grits, the First, Second, and Third, with intervening shales and ganisters, a practice apparently justified by the occurrence of three prominent features over most of the area.

The base of the series cannot be regarded as a fixed horizon however, as the Carboniferous Limestone facies persists to higher horizons in the Mid Northumberland trough than on the Alston Block with the result that the base of the Millstone Grit was taken at higher horizons in the trough area than on the block to the south (see Chap. 5, pp.338-342). To the south, on the Askrigg Block, the base of the Millstone Grit was taken at horizons which can be correlated with beds in the Upper Limestone Group on the Alston Block (see Chap. 5, pp.342-344). The position is equally unsatisfactory with regard to the upper limit of the Millstone Grit. The lowest coal within the Coal Measures is not nec~~c~~essarily the same seam from point to point. Over the Alston Block, the horizon is relatively constant, being taken at the top of the Third Grit of the primary surveyors. Dunham (1948, pp. 45, 47) adopted this practice and placed the succeeding beds up to the Brockwell Coal in the Lower Coal Measures. Available evidence suggests that these beds may lie entirely within the Communis Zone (Hopkins 1931, p. 240) though Trueman (1948, p. lxxxvi) suggests that the Lenisulcata Zone may also be represented. In Northumberland, however, Lebour (1876 pp. 225 - 237) took the upper limit of the Millstone Grit at the Brockwell Coal, while the Geological Survey placed the beds between the Brockwell and Victoria Coals in the Gannister Series (Hedley 1931, p. 238).

Woolacott (1923) described the lithology of the sequence penetrated by the Roddymoor borehole, which reached the base of the Carboniferous at 2,827 feet 6 inches below the surface, while Lee (1924) described the fauna. The Lower Coal Measures were separated from the Millstone Grit on lithological grounds, the former consisting of fine grained sandstones, the latter of coarse grits and sandstones. Four main grits were recorded associated with shale, marine beds, three 1 inch coals, one ganister and thin sandstones. The most important feature was the occurrence of two or three marine bands above the 'Felltop Limestone' (probably the Upper Felltop), which Woolacott regarded as similar in position to the Botany Beds of Garwood, and of upper D3 age. Which of the four grits corresponded in detail with the three grits of the primary surveyors is not known. A total of 258 feet 9 inches of beds were assigned to the Lower Coal Measures by Woolacott (1923, p. 51).

R.G. Carruthers (1938) concluded that the Basement Grit of Swaledale (The Tanhill or Ingleborough Grit of the primary surveyors) is on quite a different horizon to the Basement Grit of Durham. Each is accompanied by unconformity, but while that associated with the Durham Grit increases northwards towards the Tyne, the other remains relatively quiescent until we reach Swaledale. It then becomes spectacular, descending rapidly through the sequence until in North Wensleydale it almost reaches the Main (Great) Limestone. He suggested the name "Tanhill Transgression" for the unconformity (p.253). He correlated the Basement Grit of Durham with the Iron Band Grit of Lunedale and the Water Crag Grit of north west Swaledale; the Upper Felltop Limestone of the Alston Block with the Candlesieve Limestone of north west Swaledale; and the Botany Limestone with the Lower Felltop Limestone. He rejected the correlation suggested in the Mallerstang Memoir (1891) of the Mirk Fell Ganister and the Grindstone Sill; of the underlying limestone with the Upper Felltop Limestone; and of an upper part of the Ten Fathom Grit with the Firestone Sill. In effect Carruthers suggested that the upper part of the Alston Block succession is the equivalent of the lowest beds of the Millstone Grit of north west Swaledale, and only the lower part is the equivalent of the Upper Yoredale Beds.

The problem of the "Millstone Grit" and of the limits of the Namurian in the North of England are discussed in Chapter 5 (pp.335-344) following; suffice it here to say that the base of the Namurian has now been fixed by the Geological Survey at the base of the Great Limestone. ?

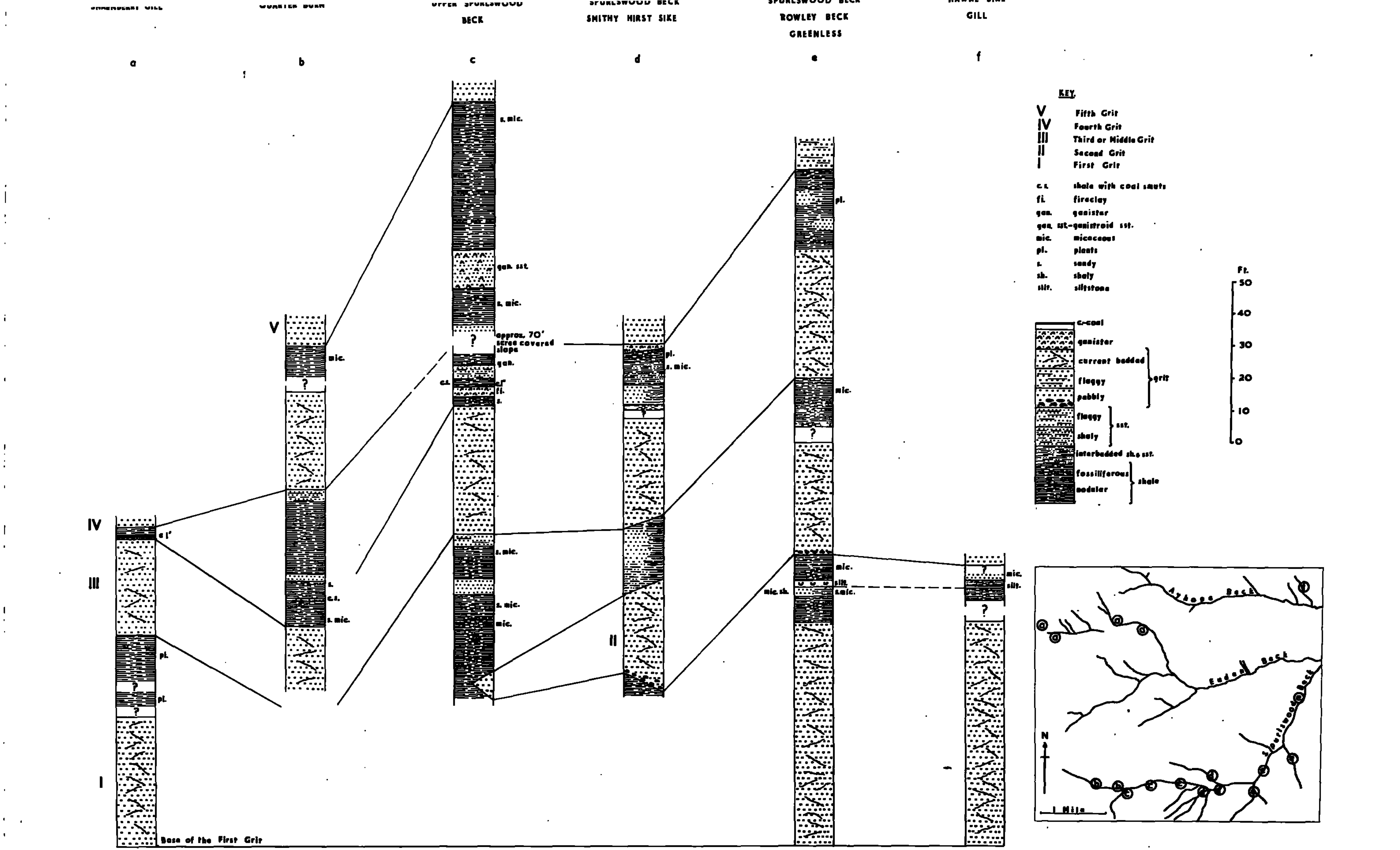
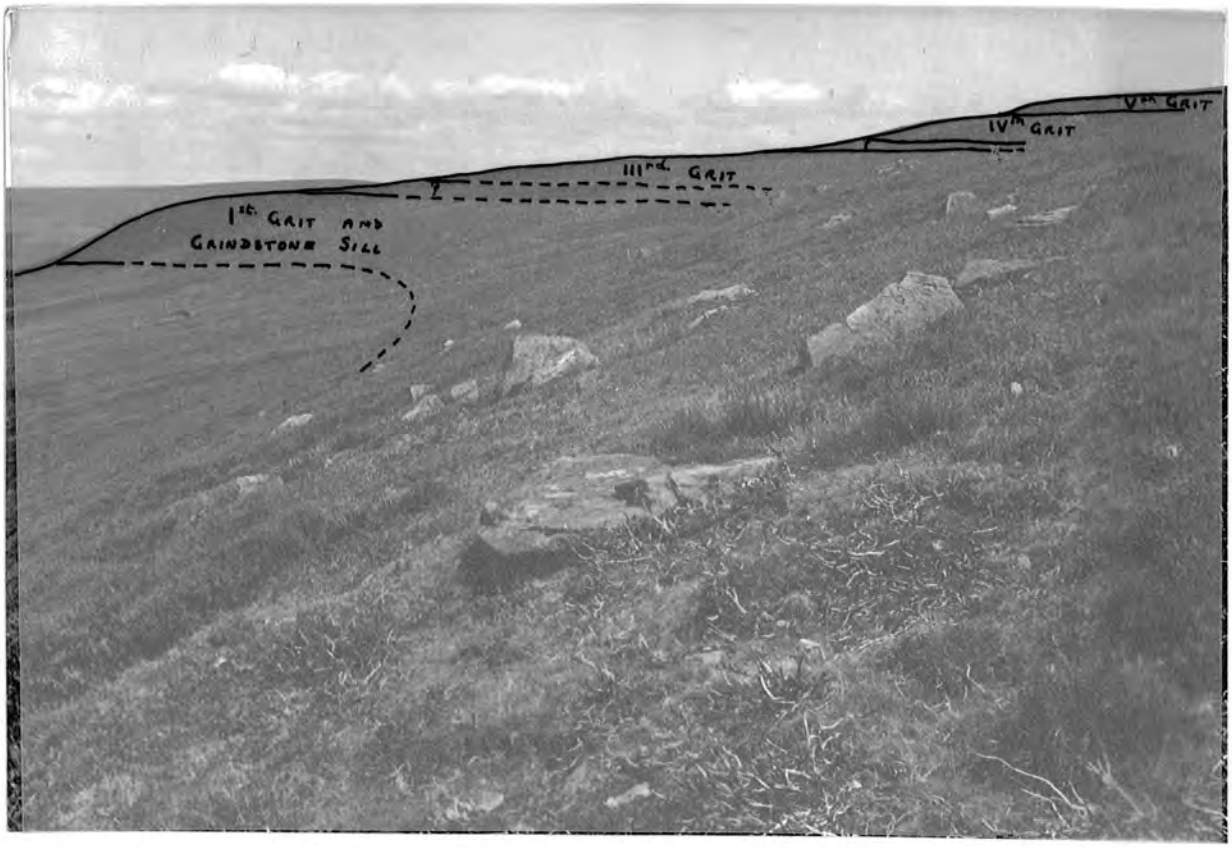


Fig. 6. COMPARATIVE SECTIONS of the MILLSTONE GRIT

Plate 9.



The "Millstone Grit" features on Brown Dodd, east of Eggleston Burn. The lower feature contains both the First Grit and the Grindstone Sill, the broad, shale-like feature above is the Middle Grit. The two uppermost features are the Fourth and Fifth Grits respectively. The Second Grit is not developed in this part of the area.

GENERAL STRATIGRAPHY.

For the purpose of this thesis the first notable grit development above the Grindstone Sill has been taken as the basal member of the "Millstone Grit" series, following the practige adopted by the primary surveyors (Dunham 1948, p. 45). The 'Third' and uppermost grit of the primary survey has been retained as the topmost member of the series, but its situation within the series is somewhat changed, being the Fifth Grit of the present survey.

The major departures from the primary surveyors' inter - pretation of the "Millstone Grit" geology of the area lie in the recognition of an incoming grit between the First and Middle Grits in the eastern part of the area, and of the presence of two grits, the Third and Fourth, where the original surveyors mapped a single Second, or "Middle Grit".

The First Grit makes its initial appearance in the north western part of the area, where it caps James's Hill, the base lying at a height of 2,075 feet O.D. To the east it descends to approximately 725 feet O.D. near the Grove (067300), largely under the influence of the regional dip. This regional tilt naturally progressively introduces higher members of the succession, so that in the country east of the Little Eggles Hope - Eggleston Burn valley, a complete sequence up to and including the Lower Coal Measures presents itself for examination.

Generally, the First Grit is a current bedded, coarse grained, frequently pebbly grit, but locally it may be medium grained or even fine grained. Quartz, much of it optically strained, forms the main constituant of the grit accounting for 60 to 70% of the sections examined. Quartzite is almost invariably present and may comprise up to 10% of the rock. The felspar content is largely corroded, varying from nil to 14%, and is notable for the almost complete absence of microcline which Gilligan (1919, p. 262) records as the dominant felspar member of the Yorkshire Millstone Grit. Micaceous minerals, consisting of hydrobiotite, but also including muscovite and chlorite, are usually present in small quantities. The clay mineral content ranges from 5 to 25 %. The heavy mineral suite is poor, the most significant fact being the absence of garnet, the commonest accessory mineral of the Yorkshire Millstone Grit (Gilligan 1919, p. 264).

The grit is but poorly exposed in the western part of the area, so that its full thickness is not known, but 35 to 40 feet is revealed in Little Eggles Hope, while a thickness of 40 feet is recorded from Sharnberry "A" Shaft, so that 35 to 40 feet would seem to be fair average thickness for the grit over the north western part of the area. To the east thicknesses of 65 to 70 feet are exposed in Ayhope Beck, and 70 to 75 feet in an old quarry in Spurlswood Gill, while 44 feet of coarse grit outcropping in the south bank quarries of Euden Beck probably do not represent anything like the full thickness of the grit. To the south, in the Eggleston area, 30 feet of coarse grit crop out on Nemour Hill, 32 feet in Stobgreen Sike, and 30 feet of pebbly grit in Pallet Crag Gill, with thicknesses of 25 feet and 28 feet elsewhere which are probably not full thicknesses. What appears to be a general easterly thickening in the north, may or may not occur in the southern part of the area. Thick grit formations east of Jagger Hill (041234) lie beyond the south eastern boundary of the area and have not been mapped.

General thick sedimentation in the underlying strata in this area is of some significance in this connection, notably the thick grit developments in the Transgression Beds Grit, the Hipple Sill, and the Grindstone Sill, and the abnormally thick shale - sandstone series above the latter (see chap. 3). Whether this represents a general easterly or south easterly thickening, or the site of a major distributary is not certain.

Finally, in Lunedale, the First Grit is poorly developed in the area surveyed, 5 feet of coarse grit on Grits Hill, being the thickest exposure encountered. This may, of course, be due to the removal of much of the grit, but Reading (1954, p. 124), reports a poorly developed First Grit (Botany Grit) transgressing across the Grindstone Sill in How Gill, approximately one mile to the south west.

The grit is usually strongly current bedded (see pl.10A, p.273). Foreset directions have been measured where possible and a northerly source is normally indicated, varying from north west to north east in the main. Numerous exceptions occur, however, as is to be expected. Thus in South Grain Beck near the lead mine, the lower beds of the First Grit frequently suggest a south easterly source, with a more normal northerly source for the higher beds. Downstream an east north easterly source is indicated in some localities, but northerly source directions predominate. A southerly source is suggested by foreset readings in Hudeshope Grains, and a south-south-westerly source on Grits Hill, Lunedale.

The base of the First Grit is transgressive, but not violently so. Recognition of the degree of unconformity is largely dependent upon the presence or absence of the green sandstone and to a lesser extent of the marine shales above the latter, but the development or lack of development of an independent First Grit feature above the Grindstone Sill also serves as an useful guide. Thus on James's Hill the First Grit gives rise to an independent feature above the Sill, and in Hudeshope Grains at least 35 feet of shales, including marine shales and a coal, are preserved below the grit. To the east on the Hudeshope Beck - Great Eggleshope Beck Watershed there is no independent feature which leads one to assume poor development of beds between the First Grit and the Grindstone Sill. A stream section on the eastern side of the watershed, in Lodgegill Sike, reveals only 4 to 5 feet of poorly fossiliferous shale between the two beds, confirming the assumption. Whether this poor development is due to transgression or not, is not clear. If the marine shales are equivalent to those in Hudeshope Grains then simple attenuation is the cause, and the green sandstone and coal are absent through non deposition. The shales are unlike those seen in Hudeshope Grains and elsewhere, and although this is poor evidence in itself, it does seem better to regard the poor fauna in these shales as a remnant fauna from the marine top of the Grindstone Sill, which is either undetected or undeveloped elsewhere.

In Little Eggles Hope, north of East Rake Vein, 9 inches of sandy shale separate the sill and the grit, the grit descending upstream until it cuts across the sill itself (see fig. 5 , p. 206). Southwards, in both banks of Little Eggles Hope, and on the eastern slopes of Eggleston Burn, no independent First Grit feature arises, again suggesting poor development of intervening beds. To the west, in Dusty Gill, a left bank tributary of Great Eggleshope Beck, 16 feet of shale, including 3 feet 6 inches of fossiliferous shale equivalent to the Hudeshope Grains marine shale, are preserved below the grit. It is significant that the First Grit forms a separate feature for a distance of 400 yards to the south. In the East and West Rake Hushes area, to the west, both the green sandstone and overlying marine shales are present, followed by 10 feet of shale below the grit, while in Horden Sike to the south, the green sandstone and marine shales are again preserved.

It appears possible that the First Grit transgression is active along one, or possibly two 'belts'. The first lies along the Hudeshope Beck - Great Eggleshope Beck watershed, lifting to east and west, the second in Little Eggles Hope and possibly continuing down eastern Eggleston Burn, lifting to the west in Dusty Gill, East and West Rake Hushes and Horden Sike. There is no definite proof of the existence of these 'belts' (particularly the second one) neither can any 'ribbon' development similar to that associated with the washout channels of the Upper Limestone Group be demonstrated. However, if the area in which the transgression lifts in Horden Sike, East and West Rake Hushes, and Dusty Gill be continued northwards, it links up with the incoming First Grit feature east of Great Eggles Hope, running from south of Harrisha Hill to Little Eggleshope Grains. Reading (1954, p. 124) informs us that the Botany Grit (which is correlated with the First Grit of Durham) is transgressive across the Grindstone Sill in Hill Gill on Botany, which lies in a direct north-south line with the Hudeshope Beck - Great Eggleshope Beck watershed, an area of active transgression. This may be of some significance.

East of Little Eggles Hope in Sharnberry Gill, the transgression is once more strikingly evident. A road cutting reveals the base of the grit cutting across shales, rising to the east (see pl. 11 , p.283). This does not herald a general easterly uplift as in Sharnberry Quarries to the east the grit has descended once more to preserve only 4 feet of shale above the Grindstone Sill (see pl. 10B, p. 273). Downstream the transgression continues to be irregular, following no set pattern or general trend, (see pp. 284). In South Grain Beck and Ayhope Beck the First Grit forms an independent feature, indicating that the transgression is not severe. To the south, in Spurlswood Gill, the green sandstone is preserved. The Eggleston area presents an interesting picture, with a greatly increased thickness of beds above the Grindstone Sill which cannot be attributed to an uplift of the transgressive plane (see pp.285). There is some evidence of transgression even here; in Pallet Crag Gill 25 feet of beds occur above the green sandstone including a thin limestone which is correlated with the marine shales above the green sandstone to the north. In Redmire Gill, 500 yards to the north west, only 8 to 10 feet are preserved, with no marine horizon.

Consideration of the nature of the transgression east of Little Eggles Hope - Eggleston Burn, leads one to discard the hypothesis of the existence of two 'belts' of transgression, as there is no general uplift to the east. The position regarding the supposed 'belt' along the Hudeshope Beck - Great Eggleshope Beck watershed remains unaltered however.

In the north and north western Millstone Grit outliers, the First and Middle Grits are separated by no more than 30 feet of beds, of which only shale is seen in a few poor exposures. The Sharnberry overflow channel offers the first important section 15 feet of shale outcropping, which has yielded fragmentary plant remains, Conularia cf. missouriensis, a fragmentary brachiopod, and Fenestellids. Downstream, in Sharnberry Gill, an estimated total of 30 feet of shales separates the two grits.

In the western, upper reaches of Spurlswood Gill, exposure below the Middle Grit is reasonably good and at least 47 feet of shales with thin sandstones occur. Downstream these shales and sandstones give way to an incoming grit, lithologically very similar to the First Grit (see p. 287). The primary surveyors ? also mapped this grit as lensing out upstream near this point, but they regarded it as the First Grit and combined it with the First Grit proper which outcrops downstream near Blackling Hole, as a single grit. Certain exposures prove that it is an independent grit above the First Grit; it is in fact the Second Grit of this thesis. The initial grit exposure is of 15 feet of coarse grit, followed upstream by an unexposed gap of 100 yards, and then a shale sequence. The grit must die out completely in this gap. Downstream it thickens, exposures of up to 40 feet of coarse grit occurring, capped by up to 20 feet of shales below the Middle Grit. [illegible]

The important sections occur 140 yards downstream from the Seavy Sike confluence. Below the grit 8 feet of shale are underlain by a 2 feet thick fossiliferous siltstone and 6 to 7 feet of shale above the First Grit. This siltstone contains Lingula mytiloides and a fragmentary brachiopod, and is considered to be equivalent to the marine shales seen in the Sharnberry overflow channel above the First Grit. It is probably at the horizon of the Botany Limestone of Stainmore, which overlies the Botany or First Grit. Downstream, in Greenless, the siltstone is once more exposed approximately 5 feet above the First Grit, with the Second Grit outcropping in the stream a few feet above.

On Pennington Rigg to the north, a bold feature overlies the First Grit. The feature is at least 40 feet high and has coarse grit outcrops to confirm its identity. Above, the Middle Grit can be mapped with reasonable confidence. Traced west south westwards the Second Grit feature becomes progressively less bold, and finally dies out completely (see pl. 13 , p. 291). Neither faulting, nor drift cover can be utilized to explain the fade-out of the feature (see pp.291-2), and it must be due to the feathering out of the grit as seen in Spurlswood Gill. This is confirmed in Acton Beck, Cloudlam Beck, and the country to the north, The base of the Middle Grit can be mapped from Acton Beck to Cloudlam Beck, and thence to Sharnberry Gill. Below this the top of the First Grit is mappable from Acton Beck to Cloudlam Beck, with no more than 30 feet separating it from the Middle Grit. No Second Grit is developed. Northwards to Sharnberry the top of the First Grit is conjectural, but there is certainly no grit development between it and the Middle Grit. There is little doubt that the Second Grit does die out to the west on Pennington Rigg.

A similar state of affairs exists on Hamsterley Common. A prominent Second Grit feature, with coarse grit exposed in some old quarries, fades out westwards, above the First Grit. Beyond this, on the northern side of the common, both the top of the First Grit and the base of the Middle Grit can be traced, and no grit intervenes. On the southern side afforestation makes mapping more difficult, but the Second Grit appears to die out east of the Black Hill Fault. It is not present further west on the western side of Black Hill, where the First Grit is overlain by a Middle Grit feature. Similarly still further west, on the Sharnberry Beck - South Grain Beck watershed no Second Grit is developed, the First and Middle Grit features being separated by no more than 30 feet, and the only exposure being 4 feet of shale in a stream west of Nanny Sike.

In Hawke Sike Gill, a tributary of Ayhope Beck, the Second Grit is present, with a thin, tough, grey siltstone situated 9 feet below, which can be correlated with the fossiliferous siltstone of Spurlswood Gill. This area is being resurveyed by the Geological Survey, who may be able to demonstrate the westerly attenuation of the Second Grit to the North.

In the Stobgreen Plantation area, the Second Grit, dipping northwards at up to 37^{o}, is marked both at the top and the base by a feature. These peter out 600 yards east of the Southern Eggleston Fault, while other grit features continue westwards for up to 300 yards. This point is taken as the feather edge of the grit. There is no proof of this, and the feature may fade out because of structural causes (see p.296). North of the Northern Eggleston Fault however, no Second Grit is developed, the First Grit being succeeded by a typical Middle Grit feature. If a line connecting the western edges of the grit on Hamsterley Common, Pennington Rigg, and in Spurlswood Gill were continued south south westwards, it would coincide approximately with the westerly fade-out of the Second Grit feature in this area. Apparently the Second Grit comes in along a north north east - south south west line in the area mapped.

The Second Grit is lithologically very similar to the First Grit, being coarse grained, sometimes pebbly (especially at the base), and current-bedded generally with a northerly source direction indicated. It has a peculiar basal structure (see pl. 12, p. 289) with curved, roll-shaped projections on the lower surface. Quartz is once more the dominant constituent forming up to 70%. It frequently shows undulose extinction and some - times a slightly biaxial interference figure. Secondary silica mantles occur on some grains, showing signs of erosion. Quartzite is again prominent, forming 38% of one specimen taken from the base, which contains large quartzite pebbles (see p.328). The felspar content consists of oligoclase and orthoclase, usually corroded, and amounts to as much as 7%. Clays account for up to 25%, much of it of a greenish colour due probably to the presence of chlorite, which can be seen in the corroded felspars. Zircon was the only heavy mineral detected.

The marine siltstone is a fossiliferous, siliceous, fine grained, grey rock. In Spurlswood Gill it consists of up to 5 or 10% of detrital material, mainly small, angular quartz grains, but also some muscovite and chlorite, set in a brownish silica. The grey colour is due to the content of black carbonaceous material. In Hawke Sike Gill the detrital material amounts to about 80%, including quartz, plagioclase felspar, hydrobiotite, muscovite and chlorite.

It has already been stated that the primary surveyors mapped three grits on the evidence of three prominent grit features over much of the area (see p. 241). Their Second, or Middle Grit presumably owed the existence of its bold feature to a capping of massive, resistant grit, as the typical Middle Grit is "a coarse sand-rock with kaolin cement " (Dunham 1948, p. 47). The presence of a grit between the First and Middle Grits has already been indicated so that the Survey's Second Grit is now the Third Grit of the present area.

Over the western part of the area no evidence occurs disputing the Survey's interpretation of the Millstone Grit geology; the Second Grit is undeveloped, and three bold features occur, the two uppermost grits forming grit scar features (see pl. 9 , p. 245). When traced around into the Sharnberry overflow channel however, evidence which disproves the primary surveyors' conception occurs. In the south bank of the overflow (000306) the Middle Grit is capped by 3 to 4 feet of ganistroid sandstone, a 1 foot coal and 3 to 4 feet of shale grading up into a sandstone. On the north bank two exposures of sandy, micaceous shale (999308 and 004308) occur above the grit. The Middle Grit can then be traced into the South Grain Beck drainage basin, and in the south bank tributary of the beck is seen to be overlain by 4 feet of shale grading up into sandstone below the Fourth Grit, the "capping" of the primary surveyors.

In Spurlswood Gill the 'Middle Grit is seen in its typical loosely consolidated condition, separated from the massive Fourth Grit, by variable thickness of strata. Near the confluence of Quarter Burn and Spurlswood Beck it is succeeded by 42 feet of shales and sandstone, including 1 feet 8 inches of shale with coal smuts (no doubt equivalent to the Sharnberry coal) and a 2 feet 3 inch tough quartzite. No ganister occurs below the coal. Above these beds comes the Fourth Grit. In the south bank of the burn near this exposure, approximately 20 feet of the grit crops out, the top 5 to 10 feet being more compact than normal, but not nearly as massive as the typical Fourth Grit (see pl. 15A, B p. 309). The succeeding beds prove to be variable, but a thin coal occurs in two further exposures in the north bank of Spurlswood Gill, near the confluence, and 500 yards downstream, where it is 2 inches thick and lies immediately below the Fourth Grit. In each case the coal is underlain by ganistroid sandstone 3 to 4 feet thick. The quartzite, 2 feet thick, is exposed 150 yards to the east of the latter exposure. It is probably the same horizon as that which is responsible for a mappable feature capping the Middle Grit on Pennington Rigg, in which quartzite outcrops.

The full thickness of 40 to 45 feet of grit is exposed in Spurlswood Gill 140 yards from the Quarter Burn confluence, with further outcrops of 30 to 40 feet downstream. In Thorny Cleugh, a south bank tributary to the east, the grit is succeeded by at least 16 feet of shale and lenticular sandstones and a 2 feet 8 inches ganistroid sandstone, below the Fourth Grit. There is no coal.

These and other exposures in Smithy Hirst Sike, and Greenless amply prove that the Middle Grit and its resistant "capping" are independent grit formations, herein termed the Third or Middle Grit, and the Fourth Grit. Over the western part of the area, there is, of course, the possibility that the Fourth Grit has transgressed down onto the Middle Grit, but in the absence of positive evidence in this direction, the latter has been mapped as an independent grit, its upper surface being drawn conjecturally, relative to the overlying Fourth Grit. This is also true of large tracts of the eastern part of the area, where the grit's contact with overlying beds is unseen.

The thickness of the Third Grit would appear to vary between an estimated 30 feet in the west, to 40 to 45 feet in Spurlswood Gill and the eastern part of the area generally. It is typically a coarse grained, yellow or orange coloured, loosely compacted grit, which according to Dunham is found in a rotted condition at considerable depths (1948, p. 47). Locally it is more compact, being a current bedded, medium to very coarse grained grit. Normally it gives rise to a more or less weak feature, being stronger where protected by the overlying Fourth Grit. On Pennington Rigg it develops a secondary feature, probably due to differential compaction as seen in Quarter Burn. Between 60 and 65% of the rock consists of quartz possessing the same optical properties as that of the lower Millstone Grits. Quartzite is once more a prominent constituent and may form as much as 14% of the rock. The felspar content is low, varying from nil to 2% in the sections examined. It is probably almost entirely corroded and represented in the abundant clay mineral content, which may account for as much as 29% of the sectioned specimens, which are of the more compact variety, and probably more in the more normal rotted grit. Mica normally occurs, accounting for up to 6%, and consisting mainly of hydrobiotite. Zircons and some schorlite occur.

The Fourth Grit is revealed in the prominent grit scar outliers capping Monks Moor, Harnisha Hill, and Jack Scars. Up to 15 feet of coarse, massive, compact grit crop out, breaking off into huge grit blocks (see pl.15A,B, p. 309). The features are flat topped and covered with peat deposits and a luxuriant growth of heather. White Hill, above Middle End, is also surmounted by the Fourth Grit, but does not form a strong grit scar feature.

Along the eastern slopes of Little Eggles Hope and Eggleston Burn, the Fourth Grit gives rise to a prominent feature running almost the whole length of the valley. Between Islington Hill and Millstone Rigg, where the overlying beds are removed, a continuous grit scar feature runs southwards for more than 1,200 yards, forming Wheel Crag. It forms a flat plateau surface with a similar grit scar on the eastern side at the headwaters of Cloudlam Beck. Below the Fifth Grit capping of Islington Hill and Millstone Rigg no grit scar is developed, but in situ exposures of up to 10 feet of grit occur, while numerous very large coarse grit blocks are scattered over the feature. In Knotts Hole, at the southern end of the feature, 23 feet of coarse grit outcrop, followed by over 24 feet of shale and sandstone, suggesting that the 15 feet or so of grit exposed to the north do not represent the full thickness. At the eastern limit of Ever Rigg, in Ever Pools, 35 feet of shale crop out below the Fifth Grit and above 10 feet of fine grained sandstone which probably represents the top of the grit, (see p. 312).

The grit is well exposed in the Spurlswood overflow channel and in Spurlswood Gill, in its typical massive development, but also showing a localized tendancy to rotten weathering identical with the Middle Grit. This is best seen in Quarter Burn, where 5 feet of massive, coarse grit cap a rotten, coarse grained, yellow and orange grit, the whole totalling 30 to 35 feet in thickness. Downstream, in a space of 30 yards or so, this loose grit can be seen to thin rapidly, while loose blocks of grit testify to the continued presence of the more typical compact grit. The grit resumes its more typical thickness and lithology to the east (see p. 317). Directly south of this exposure, in the south bank of Spurlswood Gill, the grit is again attenuated over a distance of approximately 100 yards so that there appears to be a narrow north - south belt of poor grit development in this locality. This latter exposure reveals at least 46 feet of succeeding shales below the Fifth Grit. These shales form a relatively strong feature which can be traced around Woodlands Fell almost to Greenless.

Downstream, as previously mentioned, the grit resumes its normal lithology and thickness in both banks. In the south bank, however, it becomes attenuated once more on Woodlands Fell, 6 feet of massive, coarse grit being all that is revealed in Thorny Cleugh, with a similar thickness in a stream to the east overlying shale and sandstone and followed upstream by siltstone (see p. 318). The attenuation is reflected in the weakness of the grit feature on Woodland Fell. Further east, in Greenless, at least 10 feet of grit occur, with a fairly strong feature extending downstream in the right bank of Spurlswood Gill.

In the north bank of Spurlswood Gill the grit maintains its thickness, with up to 30 feet of grit outcropping in Smithy Hirst Sike, indicating that the thinning of the grit on Woodlands Fell is southerly and not easterly.

The localized tendancy of the grit to rotten weathering may be responsible for the weakness of the Fourth Grit feature on the high ground between Sharnberry Gill and South Grain Beck (see p. 313), and possibly on White Hill (see p.309). It may also account for the development of a secondary feature occurring within the grit on Black Hill, and along the right bank of

Spurlswood Gill beyond Greenless.

Lithologically the grit is a medium to very coarse grained grit, normally massive and compact, but locally 'rotten'. Quartz, with optical properties similar to the older grits, accounts for 55 to 65% of the rock, while the quartzite content amounts to between 15 and 23% in most sections examined. Felspar is a minor constituent, 3% of corroded felspar being the greatest amount recorded. Mica, present in small quantities, consists of muscovite and hydrobiotite. Clay minerals, which may form as much as 25% of the rock, are most abundant in the coarser grained specimens. The only heavy minerals identified? located were a few small grains of zircon.

The Fifth Grit herein represents the Third and topmost Millstone Grit of the primary surveyors, succeeding beds being placed by them, and the author, in the Coal Measures.

The grit surmounts Islington Hill, with some large grit blocks littering the western edge of the feature. To the south, Ever Rigg forms the largest outcrop of the grit mapped. Its western edge gives rise to the grit scar of Millstone Rigg (which contains outcrops of fine to medium grained grit) eastwards from which the feature extends as far as Ever Pools. Apart from the Millstone Rigg scar, exposure of the grit is very poor. In the left bank of the small tributary of Quarter Burn, 10 feet of flaggy, medium grained grit, exposed immediately south of Knotts Fault, represents one of the best exposures of the grit in this area.

The next extensive outcrop of the grit mapped, extends from Grey Carrs, north of Stobgreen, through Thrindle Hills, to Woolly Hills on Woodland Fell, beneath Coal Measures. Exposure of the grit is once more very poor, apart from some very large blocks of medium to coarse grained grit on Grey Carrs, south of the Grey Carrs Fault.

High on the southern slopes of Spurlswood Gill, in the Hamsterley Forest Reserve, the grit gives rise to a feature with old grit quarries, most of which are overgrown, but with 8 to 9 feet of medium grained, current-bedded grit cropping out in one old quarry east of the Hamsterley road (067288).

Generally speaking it is a fine to very coarse grained grit, being finer grained towards the top. The coarser rock consists of 70% quartz, much of it with strained optical properties, 14% quartzite, and 16% clay minerals in the sections examined. Neither felspar nor mica were located in the thin sections but mica does occur in very small quantities in the hand specimens. Accessories include rutile and zircon. The fine grained rock is a quartzite, consisting of interlocking quartz grains and some quartzite grains. The quartz has the same optical properties as in the coarser rock. No felspar was seen, but small amounts of muscovite and hydrobiotite occur. Clays are present interstitially in very small quantities, while the heavy minerals include zircon and schorlite.

The Coal Measures occupy an area to the north east of Eggleston, capping the Grey Carrs - Coldthorn Moss area, and occurring in Hindon Beck. Exposure in the Grey Carrs-Coldthorn Moss area is very poor, the only in situ outcrops occurring in an old Cleveland Dyke quarry (032252). South of the Northern Eggleston Fault the downthrown measures are exposed in Hindon Beck.

They are a highly variable succession of shales and sandstones dipping in a general northerly direction at up to 20°.

Coal has been worked along the beck, mainly in the northern banks, the position of the seam being marked by a series of old drifts and coal tips, although the seam itself is unexposed. North of the road to Woolly Hill, a line of coal tips yields shales with mussel impressions in abundance. The contorted nature of the shales prevents specific determination of the non-marine lamellibranchs, but the mussel band is in all probability that associated with the Brockwell Seam, in the Communis Zone. The estimated total thickness of the beds between the top of the Fifth Grit and the Brockwell Coal is 200 feet.

DETAILED STRATIGRAPHY.

The First Grit

Middleton Common:- The First Grit caps James's Hill, forming a well defined feature around the hill. The flat top of the hill is thickly covered with peat, with consequent poor exposure, the Grit only being seen in a few isolated outcrops, mainly in small stream exposures. It is revealed as a coarse-grained, current-bedded, not very compact grit, of a yellowish-buff colour. No complete section of the Grit is seen, so that its full thickness is unknown; the thickest exposed section is of 10 to 15 feet of coarse grit (No. 183) in Hudeshope Grains (932322). In this latter section the foreset direction suggests a southerly source for the Grit. The base of the Grit is seen only at the head of Bleagill Sike, and in Hudeshope Grains, and it is not noticeably transgressive or pebbly.

The feature swings around the head of Hudes Hope, petering out to the east, beneath the thick peat. South-eastwards down the Hudes Hope/Great Eggles Hope watershed, it does not form an independent feature, but combines with the underlying Grindstone Sill (see p.200), suggesting that the intervening beds are attenuated, possibly due to transgression below the First Grit. The base of the Grit is marked by some springs below Carrs Hill. There are no exposures of the Grit on the Hudes Hope side of the watershed, but some loose blocks of coarse, limonite-stained, buff grit are scattered below Carrs Hill. The only in situ exposure of the grit occurs in Lodgegill Sike on the western flanks of Great Eggles Hope, where some coarse, current-bedded grit overlies 4 to 5 feet of poorly fossiliferous shale above the Grindstone Sill. This is a very much thinner sequence than that occurring

See the Lodge above states the below Shales p 208 in Hudeshope Grains where at least 30 feet of beds separate the two horizons in one stream section(see p. 200), and strongly suggests transgression by the First Grit. However, the marine horizon (unless it is a different one from that seen in Hudeshope Grains, which is at least 10 feet above the Grindstone Sill) suggests that the sequence between the Sill and the First Grit may be condensed. The suggestion that the intervening beds were poorly developed, based on the failure of the First Grit to form an independent feature, is thus borne out by this exposure. The watershed, like James's Hill, is relatively flat-topped and covered with thick peat which completely masks the underlying Grit. The regional dip is reflected in the respective heights of the base of the grit: approximately 2,075 feet O.D. on the southern tip of James's Hill, and approximately 1,850 feet on the southern tip of Carr's Hill, to the east south east representing a fall of 1 in 45.

South of Carrs Hill, on the upthrow side (Southern) of the Lodgesike Manorgill Vein, the First Grit occurs as an outlier on Monk's Moor. North of the north east - south west fault from Cat Level, a weak semi-circular feature has been taken as the base of the First Grit (see p.201). There are no exposures through the peat, and if it is the First Grit, no more than the basal 5 to 10 feet can remain, the rest having been eroded. South of the last mentioned fault, the downthrown Grit (approximately 130 feet) gives rise to the Low Monks grit scar feature on the west. Very large blocks of coarse limonite-stained grit litter the bold feature which runs southwards for almost 800 yards to the north-west - south east fault from Lodge Sike to Eggleston Burn. The top of the Grit is marked by a U - shaped feature which runs

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around Monk's Moor until once more interrupted by the north east-south west fault. The only exposure of the overlying beds is in the headwaters of the East Rake Hush stream, where a thin, dark greenish sandstone (No. 114) and some soft grey shale crop out in the stream bed, just above the base of the feature. 80 yards upstream a feature taken as marking the base of the Middle Grit occurs.

From Low Monks, the base of the Grit can be traced, flanking the north west-south east fault, to the head of Snaisgill Sike, where a fine to medium grained green sandstone is capped by a 6-inches ganister, below the grit. This green sandstone is that seen over widespread parts of the area. Just over 200 yards downstream, coarse grit belonging to the First Grit crops out in the stream, proving the existance of the fault. The Grit forms an increasingly bold feature running south south eastwards to Raven Hills where it swings eastwards and then northwards to meet the fault once more, near the head of Horden Sike. Some coarse grit exposures on Raven Hills confirm the identity of the feature, which combines with the lower Grindstone Sill to form a prominent double feature. The top of the grit is also feature-marked, but nothing is seen of the overlying beds below the Middle Grit feature. Where stepped back from the Grindstone Sill, the First Grit feature loses much of its prominence.

? much of this a reflection of G. S. [illegible]

North of the fault the grit rarely gives rise to a feature but various stream exposures serve to locate its base with reasonable accuracy, in between which exposures, it is drawn in relative to the Grindstone Sill, and the overlying shale feature. In the headwater streams of Horden Sike an approximate total of 10 to 15 feet of the Grit is revealed above shales and thin sandstones, including the green sandstone. It is a coarse, limonite stained grit, with foreset directions indicating a north north easterly or north easterly course for the Grit. To the north, some loose grit blocks, one in situ grit outcrop, and a short-lived feature west of Atheys (978286) serve as checks for the Grit's position until we reach the East Rake Hush stream, where coarse limonite stained grit, and soft, fine to medium grained, red, yellow and green micaceous grits (No. 144) crop out in the stream, all belonging to the First Grit. These colourations are somewhat unusual, but the shale feature above, and the Grindstone Sill below, both serve to check the identity of the horizon. In the stream to the north, coarse, limonite stained grit crops out over shales and sandstones. From here northwards to the north east-south west fault from Cat Level, the base is once more a conjectured line.

From the Hudes Hope/Great Eggles Hope watershed, the combined First Grit - Grindstone Sill feature swings north eastwards around the head of Great Eggles Hope to White Swangs, but is largely lost sight of around Great Eggleshope Head. The Grit itself is revealed in one of the head streams of the beck as a coarse grained grit. Down the eastern flanks of Great Eggles Hope the combined feature can once more be traced south eastwards as far as the Currick below Harnisha Hill(969317), where many large blocks of coarse grit confirm the presence of the First Grit which is otherwise almost completely concealed below thick peat. Beyond the Currick, the Grit forms an independent feature which can be readily followed east south east, then eastwards to Little Eggleshope Grains where some exposures of current-bedded, medium to coarse grained, buff, micaceous grit occur. One of these

What is a currick?

reveals 5 feet of coarse grit with the foreset directions indicating a northerly source. Beyond the Grains the feature runs indistinctly east north eastwards until interrupted by the Little Eggleshope Vein. The base of the lower feature on Harnisha Hill is taken as marking the upper limit of the First Grit rather than the base of the Middle Grit because of an exposure of sandy, micaceous, buff shale above the base of the feature. Similarly, the top of the Grit is marked by the base of a closed shale feature around Three Laws Mound (983322), and yet another shale feature north of Long Man (996319).

South of Little Eggleshope Vein, the First Grit is downthrown 98 to 84 feet (Dunham 1948, p. 307), outcropping in Little Eggleshope Beck and Candlesieve Sike as a soft, limonite-stained, current-bedded, coarse grit. Some old quarries in the northern bank of Candlesieve Sike (988314) reveal 10 feet of medium grained, micaceous grit. On the eastern banks of Little Eggles Hope, where the valley opens out, the base of the grit is delineated by a feature running east-west until interrupted by the Flake Brig - Sharnberry Vein. The top of the Grit is taken at the base of a shale feature below Jack Scars. West of the beck, the Grit crops out in an east-west stream running from the reservoirs to the beck, in two disused quarries (981309 and 983307), and in an unmapped branch of the headwaters of Wire Gill (978311). The southernmost of the two quarries is situated almost immediately north of a largely unmapped, curved northern branch of the Flake Brig-Sharnberry Vein. It was previously mapped as a mineral vein for a distance of 200 yards, west of its junction with Flake Brig Vein, but no further. Presumably mineralization died out at this point and the course of the fault was not pursued further. It downthrows to the north approximately 15 to 20 feet. A thickness of 10 feet of coarse, current-bedded, limonite-stained grit crops out in the quarry, with a northerly source indicated for the grit. South of the fault, the base of the Grit is marked, on the west, by a feature running part of the distance between the fault and the Flake Brig Vein to the south. On the east its position is conjectured. Some current-bedded coarse grit is seen in an old quarry (984305).

South of the Flake Brig-Sharnberry Vein, in Little Eggleshope Beck, the downthrown grit (approximately 120 feet) outcrops in the stream, dipping 30° south immediately south of the Vein. It is a coarse, current bedded, buff grit, with a northerly source direction in one case, an easterly source in another. It is seen to transgress across a current bedded Grindstone Sill at one point in the stream (see p.206, and fig. 5), the transgression lifting slightly to the south to preserve 3 to 9 inches of sandy grey shale above the sill.

At this point the north east - south west East Rake Hush Vein crosses the beck, upthrowing 10 feet to the south. The uplifted Grit crops out along both banks of the stream, with at least 35 to 40 feet of coarse, current-bedded, limonite stained grit being exposed in the right bank. To the south, in the right bank, the Grit forms a feature, but this loses its separate identity at Middle End, where a bold feature houses both the First Grit and the Grindstone Sill. This feature follows a winding course (influenced by the East Rake Vein) northwards to Dusty Gill where the Grit is exposed as a medium to coarse grained, current bedded grit, downfaulted against the Transgression Beds Grit by the Flake Brig Vein. The transgression below the First Grit has lifted here, with at least 18 feet of beds, including a 3 inch coal and fossiliferous shale (see p.204) preserved below. The top of the Grit is marked by a shale feature south of East Rake Vein, but is conjectural elsewhere.

It has already been mentioned that the First Grit outcrops in both banks of Little Eggleshope Beck. In the left bank it is revealed as a coarse to very coarse, current bedded grit, with some plant remains. Source directions as indicated by the false bedding, are northerly. To the south, rising above the stream banks, it combines with the Grindstone Sill to form a sinuous feature, its relative boldness depending upon the thickness of the drift which skirts it. It is most conspicuous at Brown Dodd (see pl. 9 , p.245). The actual base of the Grit is conjectural because of the lack of exposure, and the fact that it does not give rise to an independent feature. This latter fact suggests that the beds between the two arenaceous horizons forming the feature are attenuated. Such attenuation results in restricted undercutting, and consequent 'step back' of the overlying resistant horizon, thus preventing the formation of a separate feature. The top of the First Grit is also uncertain. One mile south of Brown Dodd the Grit is downthrown by the west north west-east south east fault from Lodge Sike. The combined feature is not visibly affected by the fault because of the drift apron, but the fault is exposed in Eggleston Burn to the west north west, and interrupts the Fourth and Fifth Grit features to the east south east. Beyond this, it runs southwards to the Knotts Fault

<u>The country east of Eggleston Burn and Little Eggles Hope:-</u> The First Grit is exposed in South Grain Beck. In the headwaters of the beck, soft, coarse grained, limonite stained grit dips

south east at 4^{o}. It is strongly current bedded, the foreset directions revealing a south easterly source for the lower beds, and a northerly source for the higher beds, in general. Jointing in two directions, north 70^{o} east and north 15^{o} west, is poorly developed. The southern branch of the Sharnberry Vein crosses the beck in its upper reaches, its course being readily traced to the south-west through a line of old shafts. The top of the Grit, north of the Vein, is once more outlined by a shale feature which runs below the grit feature of Pawlaw Pike (008321) and south-westwards to link up with that below Jack Scars. The north west - south east Cornish Hush Vein runs between Pawlaw Pike and Jack Scars End (with no apparent throw) and is joined by the east - west continuation of the Little Eggleshope Vein at the point where the shale feature is interrupted and stepped back (upthrown) to the north.

South of the Sharnberry Vein in South Grain Beck, the downthrown First Grit crops out in the stream bed for 200 yards before its base rises above stream level. It retains its coarse, current bedded nature, with northerly, north north westerly, and east north easterly source directions, of which the northerly directions are more persistant. The Grit is jointed, with directions varying from north 30^{o} to 44^{o} east, and north 26^{o} to 50^{o} west, with one direction of north 6^{o} east being recorded.

Downstream, in the north bank, the base of the Grit is marked by a feature, at the bottom of which are many springs. It runs for much of the way south east to the Black Hill Fault. The top of the Grit is not marked by a shale feature in the steep bank but a poorly developed feature belonging to the Middle Grit serves as an indication of its upper limit. East of the Black Hill

Fault, the downthrown Grit (20 feet) once more gives rises to a feature with numerous springs at its base, which extends eastwards towards the Meeting of the Grains (051316).

In the southern bank of South Grain Beck the higher grits are stepped back from the beck, probably due to the influence of the south easterly dip of the beds. The base of the Grit is not outlined by a feature except for a short-lived, poorly developed one near The Loop (034314), immediately west of the Black Hill Fault. The shale feature above the Grit is, however, developed, and allows relatively confident mapping of the upper limit, which can be checked in the largest of the southern tributary streams. Here some loose shale occurs above an in situ grit exposure. The grit is seen to be very coarse grained and current bedded, with southerly and westerly dipping foresets. East of the Black Hill Fault, a feature enables one to map the base of the First Grit accurately along almost the whole length of South Grain Beck (there is a gap of 400 yards), and onwards along the southern bank of Ayhope Beck to the eastern limit of the area mapped. This limit is approximately one mile east of the Meeting of the Grains. Restricted outcrops of current bedded grit occur at intervals. The top of the Grit is taken at the base of a shale feature.

The base of the First Grit is similarly recognisable in the northern bank of Ayhope Beck. A prominent feature runs the length of the beck (as mapped), swinging northwards beyond the Meeting of the Grains to flank North Grain Beck. Springs are once more common near the base of the feature, which is littered with loose blocks of coarse grit in North Grain Beck. The Grit is very well expesed in Hawke Sike Gill and in a smaller tributary of Ayhope Beck to the west, where 65 to 70 feet of coarse, pebbly in parts (No. 290), limonite stained grit crop out. It is current bedded, with foreset directions suggesting a northerly source for the Grit. The Grit is succeeded by shales, siltstone, and sandstone, below the Second Grit in Hawke Sike Gill (but see p. 295). On the western bank of North Grain Beck the First Grit feature, absent to the south, can be picked up north of a forked tributary of the beck, in which a poor exposure of coarse grit occurs.

The general dip of the beds is indicated by the run of the First Grit feature which descends from a height of 1,000 feet O.D. in North Grain Beck, to below 800 feet O.D. at the eastern limit of the area, in Ayhope Beck, just over 1¼ miles to the east south east. This represents a fall of 1 in 33. Similarly, from a height of 1,000 feet O.D. in the southern bank of South Grain Beck near the Black Hill Fault, the base of the First Grit falls to approximately 780 feet O.D. at the eastern limit of the area. This entails a descent of 1 in 30, to the east, something less than the true dip which is more south easterly.

In Sharnberry Gill to the south, the top of the First Grit is initially encountered in the stream bed 700 yards west of Sharnberry Mine (007307) as a medium grained, flaggy, buff sandstone. Downstream it resumes a more normal character, being a coarse grained, fairly loosely cemented, current bedded, limonite stained grit. The top can be fairly confidently mapped downstream, gradually rising up the valley sides. In the left bank, it can be traced up onto the ground above the valley, extending eastwards for 400 yards beyond Nanny Sike. On the right bank however, it cannot be mapped accurately above the valley sides

Plate IO.

A. The First Grit, Spurlswood Beck, showing typical strong current-bedding.

B. The First Grit overlying four feet of shale and the Grindstone Sill, and showing unusually good bedding. The location is the old quarry at the mouth of Nanny Sike, Sharnberry Gill.

and is drawn in conjecturally, relative to the Middle Grit feature.

Exposure of the Grit is good, and it generally retains its coarse grained, frequently pebbly, current bedded nature, with source directions varying from north east to north west. The transgressive nature, of the First Grit is very well demonstrated near the mine (but see p.283, and pl. 11). The best exposures of this horizon occur in some old quarries at the mouth of Nanny Sike (015309), where at least 30 feet of fine to medium grained, locally limonite stained, micaceous sandstone crops out. It is finer grained than normal, but is pebbly at the base and also comparatively well bedded (see pl.10B p.273). Mine records for Sharnberry "A" Shaft record a 40 feet 6 inches "strong hazle", which is undoubtedly the First Grit. The quarry exposures probably represent by no means the full thickness of the Grit. 600 to 650 yards east of the mouth of Nanny Sike, in the southern bank of the gill, the basal 2 to 3 feet of the Grit is seen to be crowded with plant remains (No. 196). Downstream the Grit is easily traced through intermittent exposure in both banks, almost as far as Cloudlam Beck. North of the confluence the Grit gives rise to a feature in both banks of the gill. The right bank feature swings westwards into Cloudlam Beck but dies out after approximately 200 yards. The base of the Grit can be located once more in Morton Shield Beck to the west, a tributary of Cloudlam Beck, where loosely cemented, limonite-stained, coarse, current bedded grit crops out in the stream bed. In the southern bank of the stream, a feature marks the base of the Grit, running as far as the confluence with Cloudlam Beck, where it dies out.

The base of the First Grit crops out in the stream bed where the Union and Rural District Boundary crosses Cloudlam Beck. Upstream from here, the beck is floored by a current bedded, generally coarse grained, sometimes pebbly, loosely cemented grit, for a distance of over 300 yards. It is limonite stained, being orange or yellowish in colour, a characteristic often occurring in this and other grits, but especially characteristic of the Middle Grit. Some plant remains occur. Upstream, above the Grit, some greenish coloured, flaggy sandstone crops out in the stream. As previously mentioned, the top of the Grit is conjectural over Sharnberry Flat. This is due partly to drift coverage, and partly to deep ploughing and other afforestation activities east of the Union and Rural District Boundary which marks the limit of the Hamsterley Forest. These two factors between them obscure any shale feature which may occur above the First Grit. This is true also of Morton Shield, lying between Morton Shield Beck and Cloudlam Beck. The limit of the grit outcrop in Cloudlam Beck probably marks the top of the Grit, and this can be linked up with similar exposures in Cloudlam Rake (016288), and a feature (probably shale) which runs eastwards and then southwards to the headwaters of Acton Beck, another tributary of Sharnberry Beck. Beyond this, the upper limit is once more uncertain until we reach Pennington Rigg.

The base of the Grit can be followed along Cloudlam Beck to just beyond Cloudlam Rake, in the southern bank, but is then lost sight of for a while. A feature commencing near the Morton Shield Beck confluence and running eastwards for over 700 yards enables one to fix the base once more, and can be picked up again, after a gap of 300 yards, running southwards towards Acton Beck. It cannot be followed to the stream itself, but the Grit crops out in the stream near the 1,000 feet contour. Here 15 feet of coarse grit outcrop over shales, flooring the stream for 200 yards to the south west, beyond which nothing is exposed. From here, a grit feature runs the whole length of the beck, and thence east north eastwards along Euden Beck (the continuation of Sharnberry Beck) as far as its confluence with Spurlswood Beck. [illegible] Exposure along this feature is limited because of afforestation. Some old quarries 500 yards west of Kings Crag (045294), extending for 300 yards along the southern bank of Euden Beck, afford good exposures of the horizon and its contact with underlying beds (see p. 213). At least 44 feet of coarse to very coarse grit are seen but this probably does not represent the full thickness. Approximately 650 yards east of Kings Crag, some scar exposures reveal 20 feet of coarse grit with plant remains. The top of the Grit, on Pennington Rigg, is marked by a feature which can only be mapped along the forest rides. Although somewhat restricted, this procedure enables reasonably accurate mapping of this and other features, which can be traced around Pennington Rigg until cut off by the east north east - west south west fault which extends thus far from Eggleston Burn (the Knotts Fault). The First Grit is thrown down to stream level in Spurlswood Beck, to the south.

In the northern banks of Sharnberry Gill - Euden Beck, the First Grit gives rise to a feature north of Redgate Shields (030296), which runs downstream almost to the Black Hill Fault. The base descends from 1,000 feet O.D. at Redgate Shields to below 900 feet O.D. west of the fault, reflecting the general south easterly dip. Exposure along this feature is poor, but some coarse grained, current bedded grit does crop out. East of the fault the downthrown grit is exposed in a small stream, retaining its coarse grained nature. Thence downstream, a prominent feature houses both the Grit and the Grindstone Sill, the base of the Grit being exposed only in the latter stream, and another small stream approximately 1,400 yards east north east where 11 feet of coarse, current-bedded, buff grit are revealed. Foreset directions reveal a northerly source for the beds. The feature descends less rapidly downstream because its run approaches nearer to a strike section. The top of the Grit is largely drawn relative to the overlying Second Grit, but a poor feature extending eastwards from the Black Hill Fault for up to 800 yards has been taken as the shale feature frequently observed above the First Grit. Afforestation and some drift serve to complicate mapping here again.

In Spurlswood Beck, south of the fault, the base of the Grit crops out in the stream bed 1,500 yards downstream from the confluence with Euden Beck, as a coarse, current-bedded grit, dipping east at 3°. Approximately 165 yards downstream in the left bank, an old quarry reveals at least 70 to 75 feet of coarse grit (No. 226), with foreset directions consistent with a north westerly source. Thence downstream, exposure is intermittent in both banks as far as the fault. Exposure upstream is good, enabling one to trace the Grit accurately for a distance of over one mile, until the top of the Grit crosses the stream bed 240 yards south of Blackling Hole (053274). The Grit retains its coarse, often pebbly, current bedded nature (see plate 10A, p.273) with foreset directions indicating sources varying from north north west to north north east generally, but one east north easterly source direction was recorded 300 yards downstream from

Blackling Hole. The top of this horizon can be mapped confidently through various exposures in the left bank, while in the right bank a feature can be mapped along the forest sides of Front Plantation, fixing its position from the fault to Greenless. ? location Here, the top of the Grit and succeeding beds are exposed in the stream. From here to Blackling Hole, it is drawn in relative to the overlying strata. The grit is jointed in two directions at Greenless Hole - north 10° west, and north 35° east, near Blackling Hole, north 25° to 50° west, and north 35° to 60° east. At Blackling Hole a dip of 3 or 4° to the south west was recorded.

The Eggleston area:- Immediately south of the Knotts Fault an old quarry (991261) (which worked the Whin Dyke occupying the line of the fault) reveals 20 feet of coarse, pebbly grit belonging to the First Grit. It is jointed in two directions, north 65° east, and north 25° west. A feature runs to the east south east for almost 700 yards before being interrupted by a north west-south east fault downthrowing to the north east. North of the fault the downthrown horizon is drawn in conjecturally as an inverted V shaped outcrop around Blackton Beck; there are no exposures or features betraying its presence beneath the drift. The fault is mapped on the evidence available from overlying strata.

South of Blackton Beck the First Grit forms the bold feature of Nemour Hill, rising from the thick drift of Blackton Beck. 30 feet of pebbly, current bedded grit (No. 92) crop out in the hill. From Nemour Hill the feature runs south eastwards until interrupted by the Northern Eggleston Fault on Stobgreen. The upper limit of the Grit is uncertain, its position being mapped relative to the overlying Middle Grit feature, but an exposure of coarse grit, the First Grit, in an old quarry (004249) near the base of this feature serves as a check. The Nemour Hill feature, and those of the overlying grits, dip north eastwards to the previously mentioned fault, presenting excellent dip slope features.

South of the Northern Eggleston Fault, the First Grit outcrops as 32 feet of coarse, flaggy grit in the headwaters of Stobgreen Sike, dipping north at 37° between this fault and the east south east - west north west fault running down Redmire Gill (see p. 215). East of Stobgreen Sike a feature due to the First Grit runs along the northern bank of Redmire Gill gradually descending until the base of the Grit is near stream level east of the north bank tributary of the gill. Exposure is good, with numerous crag outcrops along the top of the valley revealing coarse current-bedded grit (No. 285), dipping north at 35°. The top of the Grit in Stobgreen Plantation is marked (east of the sike) by a feature as the bed dips steeply below succeeding strata. In the adjacent Barnard Castle Allotment, this feature is not discernible but the overlying Second Grit feature runs part of the way through both the plantation and allotment, serving as a guide. In the north bank tributary of Redmire Gill, 28 feet of coarse, flaggy grit are exposed, but a patch of drift probably obscures the actual top of the Grit. The First Grit continues along the North bank of the gill and is well exposed just north of the Woodlands-Eggleston road, where 25 feet of medium to coarse grained grit dips north east at 20 to 25° into another, north west - south east fault.

South of the Redmire Gill Fault, the downthrown First Grit crops out on top of a prominent feature north of Adders Gill which also houses the Grindstone Sill. 10 feet of medium to coarse grained, current bedded grit are revealed, while to the north west, 7 feet of grit dip north north west at 23° into the fault. The feature is downthrown approximately 10 feet to the east by a north north west - south south east fault on the east, beyond which it follows a sinuous course to Pallet Crag Gill. Here, in the gorge below Birch Cottage (027236), 30 feet of coarse, pebbly grit outcrop over beds dipping north north west at 28°. Beyond the gill, the feature runs eastwards for over 450 yards before being downthrown approximately 10 feet by the Southern Eggleston Fault. The feature then runs eastwards to the limit of the area mapped, with exposures of 15 feet of coarse flaggy grit in an old quarry (032234), and 20 feet of coarse, pebbly grit (No. 329) a few yards to the east. Underlying beds dip north at 14°.

Lunedale:- The only First Grit exposure in that part of Lunedale mapped in the present survey, occur on the summit of Botany Ridge. West of West Rowe Sike, a roughly east - west fairly weak feature contains some old quarries in which 5 feet of coarse, current bedded grit occur. Foreset directions suggest a south south westerly source. South of Swarthy Top, the Grit is upthrown a few feet by a west north west - east south east fault, the interrupted feature afterwards continuing its run to form the aptly named "Millstone Grits".

The Transgression below the First Grit.

Recognition of a definite transgressive plane, as distinct from minor irregularities normally associated with the bases of arenaceous horizons, depends largely, of course, upon the presence or absence of marker horizons in underlying beds. Thickness variations in themselves are generally not proof unless accompanied by visible evidence of transgression across bedding planes, as they may equally represent differential sedimentation. The green sandstone, and to a lesser extent, the marine shales, both dealt with in the previous chapter, serve as useful yard-sticks to the degree of transgression below the First Millstone Grit.

On James's Hill, the fact that the First Grit and the Grindstone Sill form independent features, suggests a fairly thick intervening succession, and in Hudeshope Grains at least 35 feet of shales and sandstones, including marine shales, occur below the First Grit. A short distance to the north approximately 10 feet less of shales, above a recognisable coal (see p.100) are preserved, the disparity being probably due, in part at least, to transgression. The green sandstone is not seen on James's Hill, unless it is represented by a 2 inch thick pyritous, greenish - grey siltstone cropping out 4 feet below the First Grit at the head of Bleagill Sike. If this is the local representative (and, like the normal green sandstone, it is chloritic, but finer grained - see p. 100) then apparent absence over the rest of James's Hill may be due to non-exposure. Its recognition as the green sandstone would also entail the absence of at least 26 feet of shales (including the marine shales and underlying coal) at this point, through transgression.

To the east, on the crest of the Hudes Hope - Great Eggles Hope watershed, the relationship of the First Grit to the underlying beds is revealed only in Lodgesike Gill, where but 4 to 5 feet of soft, poorly fossiliferous grey shale separates the Grit and the Grindstone Sill. This shale may represent the marine shale seen in Hudeshope Grains, but it is lithologically very unlike the tougher grey shale occurring there. This in itself is not a very potent objection, but correlation of the two shales entails the definite absence of the green sandstone (below the marine shales) which may be present to the west, and certainly occurs over much of the rest of the area, as well as a coal. All this is by no means impossible, but it does seem better to regard it as a poor, remnant fauna, from the underlying marine top of the Grindstone Sill (see p. 203). This alternative has been adopted; the equivalent shales may be undetected or undeveloped elsewhere. The attenuation would seem to be due, therefore, to transgression, and is general over the watershed as a whole, as suggested by the failure of the First Grit to form an independent feature above the Grindstone Sill. The situation is similar along the greater length of eastern Great Eggles Hope, no beds being revealed between the two horizons, and with the First Grit forming a separate feature only as it swings around towards the head of Little Eggles Hope, apart from a short-lived appearance in north east Great Eggles Hope.

South of the Little Eggleshope Vein in Little Eggles Hope, there is little evidence concerning the development of transgression below the Grit. South of the Flake Brig Vein, however, the First Grit probably transgresses across the top of the Grindstone Sill itself in the stream bed, rising slightly to the south, to preserve a few inches of sandy shale above the Sill, immediately north of the East Rake Vein (see fig. 5). Southwards down Little Eggles Hope and the eastern flanks of Eggleston Burn, lack of exposure prevents any definite statements concerning transgression, but the First Grit and Grindstone Sill combine to form a single feature, which strongly suggests poor development of intervening beds.

The First Grit forms a briefly independent feature on eastern Middle End, but rapidly loses its separate identity. Nothing is seen of the intervening beds until we reach Dusty Gill, to the north west, where the transgression has lifted sufficiently to preserve over 16 feet of shales, including 3 feet 6 inches of fossiliferous shales below the Grit. No green sandstone is seen, but this is probably due to non exposure. It is significant that the First Grit gives rise to an independent feature to the south for 400 yards, before dying out around the southern margins of Middle End.

On the western flanks of the Monk's Moor outlier little is known of the extent of the First Grit transgression. On the eastern flanks, near Horden Allotment, however, beds between the Grit and the Grindstone Sill are brought to light. In the head-waters of Horden Sike, both the green sandstone and overlying marine shales are present so that the transgression is not very active here. Similarly, to the north in the East and West Rake Hush area, the green sandstone and marine shales occur followed by at least 10 feet of shales and thin sandstones below the First Grit.

There appears to be two belts of transgression, the first occurring along the Hudes Hope - Great Eggles Hope watershed, lifting to east and west; the second in Little Eggles Hope (lifting to the west in Dusty Gill) and possibly continuing down the eastern slopes of Eggleston Burn. There is no proof that the

Plate II.

Unconformity below the First Grit, Sharnberry Gill. The light coloured band visible above the level of the mechanical dumper is a twelve inch thick band of grey and orange mudstone, while the base of the First Grit runs just below the line of ferns. Eighteen inches of shale separates the two horizons on the left, six feet of shale on the right.

transgressive plane does in fact occur in the form of two 'belts' similar to the 'washout' channels in the Upper Limestone Group. Neither can any ribbon sandstone or grit developments be demonstrated, but the area in which the transgression lifts, in Horden Allotment, East and West Rake Hush, Dusty Gill, if continued northwards, links up with the line of the incoming First Grit feature in eastern Great Eggles Hope, which was taken as suggesting preservation of thicker beds above the Grindstone Sill. Reading (1954 p. 124) describes how the Botany Grit (correlated with the First Grit) transgresses across the Grindstone Sill in Hill Gill on Botany Ridge, this lies in a direct north - south line with the Hudes Hope - Great Eggles Hope watershed, which may be of some significance. In that part of Botany mapped during the present survey, the Grindstone Sill feature is seen to die out eastwards below the First Grit of 'Millstone Grits' and Grits Hill, to the north and north north east of How Gill. This 'dying out', however, may be partly due to the influence of the West Pasture Road Vein, which may extend this far (see p. 222).

Just over a mile east of Little Eggles Hope, where the First Grit is seen to transgress onto what is probably the Grindstone Sill, the Grit is seen to be actively transgressive at Sharnberry Lead Mine (see pl. 11 , p. 283). A road cutting reveals a 1 foot orange and grey coloured clay or soft mudstone (some 6 to 10 feet above the Grindstone Sill) surmounted by 18 inches of shale below the First Grit at the western end of the section, increasing to 6 feet at the eastern end. This does not herald a general easterly uplift, as in some old quarries approximately 400 yards further east along Sharnberry Gill (015309), only 4 feet of black shales separate the Grindstone Sill and First Grit (see pl.10B, p.273). A further 500 yards east, 15 to 20 feet of shale and sandstones cap the Sill below the Grit. The transgression comes down once more to the south east, only 2 feet separating both horizons 600 yards north of Redgate Shields, while to the west in Morton Shield Beck and Cloudlam Beck, the intervening beds, although but poorly exposed, do not appear to be very thick.

Due south of Redgate Shields, in Acton Beck, 10 feet of shaly mudstone cap the Sill. Eastwards from Redgate Shields the First Grit develops a separate feature, and in the small northern tributary of Euden Beck, approximately 14 feet of shale and sandstone succeed the Grindstone Sill. Downstream the First Grit does not form an independent feature. In the southern bank of Euden Beck, some old quarries (045294) stretching for 300 yards, reveal the contact. At the western end the First Grit lies directly on the Grindstone Sill, but the transgression lifts to the east to preserve 3 feet of shale in one exposure, while another exposure further east leaves a gap of 10 to 15 feet unaccounted for between the uppermost sandstone and lowest grit exposures. Thence downstream the contact is not seen, but the Grit forms a distinct feature, which it does not do in the north bank of Euden Beck.

In the South Grain Beck - Ayhope Beck stream sections, exposure of the intervening beds is poor, the best exposure occurring near South Grain Beck Lead Mines (022322) where at least 6 feet of shale and sandstone succeed the Grindstone Sill. The First Grit forms a separate feature throughout the length of the valley mapped, suggesting a not too active transgression.

In Spurlswood Beck the green sandstone occurs 2 to 3 feet above the Grindstone Sill and is separated by a 4 feet gap from the First Grit.

The Eggleston area presents a vary different picture, thus in the northern tributary of Redmire Gill, although only 8 to 10 feet separate the green sandstone and First Grit, at least 40 feet of beds occur below the green sandstone, with no sign of the underlying Grindstone Sill. In Pallet Crag Gill to the south, the transgression has lifted somewhat to preserve up to 25 feet of beds above the green sandstone, including a thin limestone correlated with the marine shales occurring above the sandstone elsewhere. Below the sandstone, between 60 and 65 feet of shale and thin sandstones succeed the Grindstone Sill. This represents vastly thicker sedimentation than in the remainder of the area, rather than a simple uplift of the transgression. It is possible that the green sandstone in this area is not the same as that elsewhere, but it is lithologically very similar, and no comparable horizon occurs between it and the Grindstone Sill. Also, no marine horizon other than the limestone occurs; its relationship to the green sandstone is correct, and on the whole it seems better to correlate the green sandstone and the limestone of this area with the green sandstone and marine shales to the north and north west and invoke heavier sedimentation. The alternative is to suggest an uplift of the transgression coupled with the dying out of the green sandstone in this area, with a similar sandstone coming in higher in the succession. This seems less likely than the former suggestion, which is also supported by the lack of a marine horizon below the green sandstone.

In the western part of the Eggleston area no evidence is available concerning the transgression.

Beds between the First and Middle Grits; the Second Grit.

Monk's Moor and the country to the east:- The beds above the First Grit first occur on Monk's Moor. The top of the First Grit is outlined by a shale feature, and in the headwaters of the stream running into East Rake Hush, some sandy shale and a greenish, fine grained sandstone (No. 114) are exposed within the feature. Next exposures above this are of the Fourth Grit, a prominent scar forming coarse grit. No sign of the Middle Grit is seen other than an obscure feature marking its base on the eastern flanks of Monk's Moor.

South of Monks, in Raven Hills, both the top of the First Grit and the base of the Middle Grit are outlined by features, but nothing is seen of the intervening beds, which cannot be much more than 30 feet thick. The situation is similar on White Hill, Middle End, and down the eastern slopes of Little Eggles Hope and Eggleston Burn, with non-exposure of intervening beds.

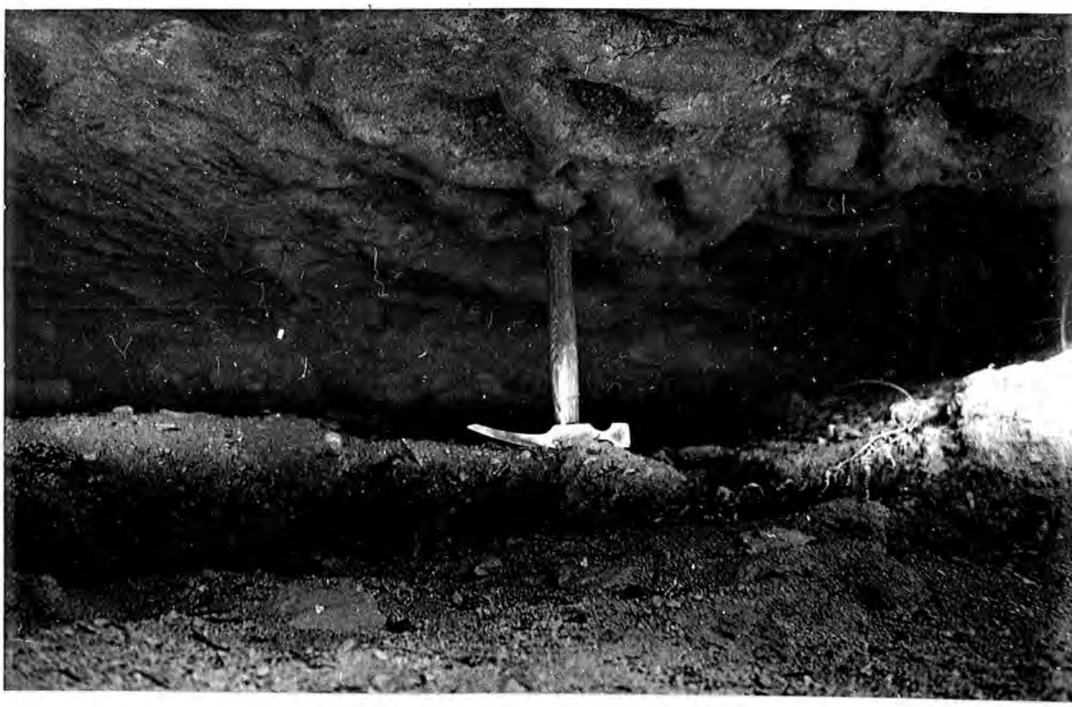
At the western end of the Sharnberry Overflow channel a total of approximately 15 feet of dark grey or black, limonite stained shales are exposed below the Middle Grit. The shale contains fragmentary plant remains, and in addition has yielded Conularia cf. missouriensis, a fragmentary brachiopod, and Fenestellids in an exposure near the Stanhope Road (997307). Eastwards along Sharnberry Gill, isolated shale exposures occur, with an estimated total of approximately 30 feet occurring between the base of the Middle Grit and the top of the First Grit which is exposed in the stream bed 700 yards east of the first mentioned shale outcrop. East of this the base of the Middle Grit rises on to the higher inter-stream plateaus of Sharnberry Flat in the south, and the Sharnberry Beck - South Grain Beck watershed in the north, forming relatively poor features above the First Grit. . At this point, it would be more advantageous to consider the succession in Spurlswood Beck, to the south, rather than continue eastwards in the Sharnberry area.

The Middle Grit crops out near the confluence of Quarter Burn and Spurlswood Beck, the base of the grit outcropping 140 yards east of the confluence. Thence downstream the grit is readily traced in either bank for a mile or more. Exposure below the grit is fairly good, with numerous scattered shale exposures in the stream banks. 500 yards downstream from the confluence, the following succession is exposed below the Middle Grit

	Ft.	Ins.
Medium grained flaggy buff sandstone passing down into:	4	0
Sandy micaceous shale grading down into) Dark grey fine grained shale)	10	0
Medium grained buff micaceous sandstone	5	0
Sandy micaceous buff shale grading down into:	6	0
Fine grained, dark grey micaceous shale	3	0
Fine grained buff shale	9	0
Dark grey, fine grained, limonite-stained shale.	8	0

This is somewhat thicker than the corresponding beds in Sharnberry Gill, and the First Grit is not yet exposed. Approximately 1,100 yards further downstream, an exposure of 15 feet of coarse, current bedded, limonite stained grit, lithologically identical with the First Grit occurs. When traced upstream however, it is seen to die out, giving way to sandy shales with thin shaly sandstones. Between the exposure of grit and those of shales and sandstones upstream, there is approximately 100 to 120 yards of largely unexposed ground, but the grit on the one hand, and shale and sandstone on the other, are undoubtedly on the same stratigraphical level. The obvious explanation is faulting, but the overlying Middle and Fourth Grits can be traced uninterruptedly along both banks of the gill. One is forced to adopt the view that this is an incoming grit, and confirmation of this is forthcoming to the east. Downstream from the first outcrop of the grit (the Second Grit), exposure is very good in both banks, with 22 feet of medium grained, current bedded, micaceous grit cropping out 400 yards to the east, and at least 40 feet of current bedded, limonite-stained, coarse grit outcropping a further 400 yards to the east, both exposures being in the fight bank. The grit is downfaulted a few feet to the east, approximately 100 yards downstream. Immediately west of the fault 35 feet of the grit (coarse, but finer grained towards the top) is capped by 10 to 15 feet of silty grey shale and sandstones below the Middle Grit. The downthrown grit outcrops in the stream bed and banks for 110 yards before being upthrown a few feet. These trough faults are parallel and follow a course west of north. Immediately west of the second (easterly) fault, 20 feet of sandy, micaceous grey-buff shales with ironstone nodules occur between the Second and Middle Grits. The top of the grit crops out in Smithy Hirst Sike on the 900 feet contour, capped by sandy, micaceous, limonite stained grey shales. Beyond the second fault, the grit continues to be well exposed in both banks of Spurlswood Gill, displaying prominent current bedding with foreset directions consistent with a northerly source.

Plate 12.



Flow casts on the base of the Second Grit, Spurlswood Beck.

A distance of 400 yards east of the sedond trough fault, the base of the grit is revealed just above stream level for a few yards before descending once more. The base is coarse grained and pebbly and has peculiar curved, roll-shaped projections, obviously moulds of sedimentary structures in the underlying shales. They correspond closely to structures described by R.R. Shrock (1948, pp. 156-161) which he calls "Flow Casts" (see pl. 12, p. 289). 300 yards downstream the base reappears and can be traced accurately for over half a mile. In the right bank of the stream, immediately downstream from the mouth of Rowley Beck, the lower 20 feet of the grit are seen overlying soft, grey, micaceous shales. The base of the grit once more displays the flow cast structures seen upstream. In the opposite bank 25 feet of coarse grit crop out. Exposure continues to be good downstream the grit outcropping in both banks and underlying strata in the stream bed. Near the Seavy Sike confluence, sandy shales and shaly sandstones outcrop in the stream, dipping west south west at 5° near the confluence, but changing rapidly to a northerly dip of 3° or 4° just over 100 yards upstream. Jointing in one direction occurs, north 47° east. In the left bank opposite the confluence, the grit shows well developed current bedding, with a northerly source indicated.

140 yards downstream, an important exposure occurs in the steep left bank of an abandoned meander (the new course of the stream is not mapped on the 6 inch O.S. sheet). 18 feet of the grit are exposed, the base retaining its characteristic sedimentary structure (see pl. 12, p. 289). The grit is coarse grained, pebbly at the base, and foreset directions once more indicate a northerly source. Below the grit, 8 feet of grey,

micaceous shale overlie a 2 feet thick, fine grained, grey siliceous siltstone (No. 218) which contains Lingula mytiloides, and other fragmentary brachiopods. This in turn overlies some sandy, micaceous, grey shale. 40 yards to the east, where the new stream course joins the old, a similar succession occurs:-

		Ft.	Ins.	
Coarse grit.				
Gap in succession		8 -	0	
Grey, siliceous, fossil siltstone.		2 -	0	(No.217)
Grey, micaceous shaly sandstones.		3 -	0	
Grey shales or mudstone.		2 -	0	
Gap in succession	1 Ft. to	2 -	0	
Coarse, flaggy grit.				

This lower grit is the First Grit which has already been traced upstream to this point from Oak Bank (see p. 277). The fossiliferous siltstone lying above the First Grit is probably equivalent to the poorly fossiliferous shales seen at the head of the Sharnberry overflow. It can also be correlated with the Botany Limestone of Lunedale, occurring above the Botany Grit, which has been correlated with the First Millstone Grit of Durham (see p. 341).

In the left bank of the gill, the Second Grit is lost sight of for a while, but can be readily linked up with exposures in a left bank tributary approximately 650 yards downstream. Both the First and Second Grits outcrop in the stream together with some intervening shales, but the marine siltstone is not seen. In the right bank the base of the Second Grit can be traced as far as Blackling Hole (053275), but is then lost sight of until exposed in Greenless. These two localities can be confidently linked up however, maintaining a constant level on or near the 800 feet contour. In Greenless, the exposed top of the First Grit is succeeded, after a gap of approximately 5 feet, by the fossil siltstone (No. 215) the top 6 to 9 inches of which is exposed. It is jointed in two directions north 30^{o} west, and north 35^{o} east. A few feet above, the Second Grit is exposed in the stream bed. Its full thickness is not revealed, and no overlying beds are seen below the Middle Grit. Thence downstream in both banks, the grit is largely mapped conjecturally in relation to associated beds. Numerous features have been mapped in the forest rides along the right bank, including one which has been taken as marking the base of shales etc., above the First Grit, and a higher feature regarded as marking the base of the Middle Grit. These two features have served as controls in mapping the base and top of the Second Grit. No exposures of the grit occur north of Greenless in the right bank. Apart from some exposure in tributary streams and a short lived feature in the left bank, the top of the grit is drawn entirely in relation to the overlying Middle Grit, the base of which can be fixed with greater confidence in this heavily afforested area.

On Pennington Rigg afforestation is in an advanced stage of development at the eastern end, but less well developed further west. Mapping has been largely confined to forest rides. Nevertheless a reasonably accurate appraisal of the solid geology is possible. A bold feature at least 40 feet high rises above the First Grit (which has been traced from the Knotts Fault, along Euden Beck, Sharnberry Beck, and the various tributaries) on the eastern end, and scattered outcrops of coarse, current bedded grit (No. 231) establish its identity. Numerous features have been mapped along the rides, which can be linked up with reasonable confidence, and checked from high ground north of Euden Beck, and also from aerial photographs. The top of the grit is marked by a feature with quartzite exposures. The Second Grit feature contains a secondary feature within it which might be regarded as marking the top of the grit. There are certain arguements against this however. Firstly there are grit exposures in both, and very little step back at the second feature. The Middle Grit is typically a rotted grit which forms poor, almost shale-like features, while the upper part of this dual feature is bold. Secondly, the possibility of it being the Middle Grit is precluded by the presence of a higher feature containing typical Middle Grit exposures. The reason for this subsidiary feature is not known; it might reflect differential compaction.

When traced west south westwards along Pennington Rigg the feature becomes less and less prominent, and finally dies out (see pl. 13, p.291). This might be attributed to drift cover, and some drift is present, but not in sufficient quantities to mask such a bold feature. It might also be attributed to faulting, but the First Grit has been traced uninterruptedly along Euden Beck and Acton Beck, while the feature marking the top of the Middle Grit is also undisturbed.

The base of the Middle Grit can be traced almost continuously from Acton Beck to the head of Cloudlam Beck and thence northwards to Sharnberry Flat and Sharnberry Gill. The top of the First Grit is also mappable between Acton Beck and Cloudlam Beck, where it lies no more than 30 feet below the base of the Middle Grit. Some thin fine to medium grained, flaggy sandstone (no more than 4 to 5 feet) is seen, but no grit between the First and Middle Grits. Thence northwards to Sharnberry Gill the top of the First

Grit is conjectured, but there is certainly no development of grit above it other than the Middle Grit.

The dying out of the bold feature on Pennington Rigg must then, mark the dying out of the Second Grit. The precise point at which the grit feathers out is not known. Two poor features occur in a forest ride running north north west from near Low Acton Currick (036283) and these are the final indications of the presence of the Second Grit. West of this the grit has been petered out conjecturally.

North of Euden Beck, on Hamsterley Common the situation is similar. A prominent feature runs along the eastern part of the common, its base marked by numerous springs on the southern side, overlooking Euden Beck. Old quarries (058304 and 064305) reveal very coarse, limonite-stained, loosely cemented grit, lithologically very similar to the Middle Grit, while exposures approximately 550 yards to the west, in a small stream (050304), reveal a more compact, coarse grit. Eastwards from this stream, and around to the north, overlooking Ayhope Beck, mapping is unhampered by afforestation, and the feature can be accurately traced. Even so it is not easy to fix the point at which the grit fades out exactly, largely due to non exposure, peat, and the profuse growth of heather. The base of the Middle Grit is marked by a poor feature running eastwards from the Black Hill Fault. After a run of 800 yards it appears to split into an upper and lower feature, the upper one dying out as it swings southwards across the common. The lower feature runs into the Second Grit feature, and this point has been taken as marking the western edge of the grit. Features caused by relatively unresistant beds (such as the Middle Grit) tend to become even less conspicuous when running across a spur (rather than along it) where erosion is less effective and where they are not worn back to protective higher beds as rapidly. It is not surprising, therefore, that the Middle Grit feature peters out when it swings southwards. A short-lived, inconspicuous feature has been taken as the delineation of a shale outlier above the Second Grit on Hamsterley Common. In the Forestry Reserve on the southern side of the common, mapping of the Second Grit feature westwards is uncertain, but features can once more be mapped along forest rides. The Second Grit appears to die out near the Black Hill Fault.

West of the Black Hill Fault, the First Grit has been traced continuously along the northern bank of Sharnberry Gill and the southern bank of South Grain Beck. Black Hill is capped by the Fourth Grit, with a feature marking the base of the underlying Middle Grit. This feature is terminated on the west by a north north east - south south west fault which downthrows to the west, bringing the Fourth Grit down 10 feet or so to form another closed feature, with the Middle Grit feature repeated below it. There is insufficient room between this latter feature and the top of the underlying First Grit for any thick grit development.

There is a saddle west of Black Hill (possibly a glacial overflow) with features formed by the Middle and Fourth Grits west of it which can be traced around the watershed to Sharnberry Gill and South Grain Beck. In Sharnberry Gill the top of the First Grit and the base of the Middle Grit can be traced with reasonable accuracy to beyond Nanny Sike. The two are separated by no more than 30 feet, and the only exposure is of 4 feet of black shale in a stream to the west. Any significant grit development would form a feature and probably be exposed. It has already been pointed out (p.286) that in Sharnberry Gill, to the west, an approximate total of 30 feet of shale, with no grit, occurs between the First and Middle Grits.

On the southern flanks of South Grain Beck both the base of the Middle Grit and the upper limit of the First Grit are once more marked by features. Here again no Second Grit is developed, only loose shales being seen between the two grits in the south bank tributary of the beck.

In Hawke Sike Gill, a north bank tributary of Ayhope Beck, some beds above the First Grit are exposed in the fork near the head of the stream. Approximately 5 feet below the Second Grit, 2 feet of fine grained sandstone overlie 2 feet of silty, grey, limonite-stained shale, and a tough, siliceous, slightly micaceous, grey siltstone (No. 291). No fossils were found, but its lithology is such that there is little doubt that it represents the marine siltstone found in Spurlswood Gill. Mapping was not continued beyond this point, but the ground is being resurveyed by officers of the Geological Survey who may be able to demonstrate the westerly attenuation and dying out of this grit in the area to the north.

The Eggleston area:- The First Grit is readily traced along the northern banks of Redmire Gill. Above it, to the north, a confusing run of 6 features can be mapped, confusing, that is, until one recalls the steep dips of up to 37° to the north recorded in the First Grit, and confirmed by a dip of 35° to the north east in the Middle Grit north east of Death Nook (018243). Reading northwards, the six features mark respectively, the top of the First Grit, the base of the Second Grit, the top of the

Second Grit, the top of the Middle Grit, the base of the Fourth Grit, and the top of the Fourth Grit. The Fifth Grit is not seen here. The western ends of these features curve slightly to the south, dying out approximately 300 yards east of the Northern Eggleston Fault. The subsidiary southern branch of this fault (not to be confused with the Southern Eggleston Fault, see p. 156) might in fact be active beyond the Redmire Gill Fault, where it has been terminated on the map. The feature outlining the top of the Second Grit dies out 300 yards further east and the grit has been petered out near here on the map. There is no proof that the grit does die out here, and the feature may peter out because of structural causes. However, north of the Northern Eggleston Fault, in the Nemour area, the Second Grit is not developed. Close above the First Grit a typical, rather weak Middle Grit feature occurs, capped by two relatively thin grit scar features assigned to the Fourth and Fifth Grits.

If a line is drawn connecting the western extremities of the Second Grit in the north and then continued southwards in a south south west line, it roughly coincides with the westerly fade-out of the feature in this area. It would appear that the Second Grit comes in along a north north east - south south west line in the area surveyed.

The Second Grit can be traced eastwards for just over 500 yards beyond Death Nook, after which it is concealed by a patch of drift, and then thrown down by the north west - south east fault north of Redmire Gill.

The final exposure of the grit is as an outlier capping the First Grit feature north of Adders Gill (see p. 279). It forms a feature terminated on the east by one of the two north north west - south south east faults running between the Redmire Gill and Southern Eggleston Faults (see p. 216). The grit apparently dips west south west at 43°. It is a coarse grained, flaggy, limonite-stained, brown grit, with a calcareous cement; 4 feet are exposed, but on account of the apparent dip the true thickness is unknown. If the grit does die out near Death Nook, 2 or 300 yards to the north, then the grit cannot be very thick here, and this dip may possibly represent, at least in part, a 'dip' off the upper surface of a lensing-out grit. The calcareous nature of the grit here is not duplicated elsewhere in the area.

The Middle or Third Grit and the beds to the base of the Fourth Grit.

The North Western Outliers:- The Middle Grit is preserved on Monk's Moor below the resistant scar-feature-forming Fourth Grit. The Middle Grit is not exposed, but its base is outlined by an ill-defined feature below the eastern edge of Monk's grit scar. It runs in a slightly sinuous course south eastwards, and is cut by the headwaters of the East Rake Hush stream, but no grit crops out through the thick peat which covers the moor. Below the feature some shales and a thin green sandstone (No.114) are exposed. The top of the grit is not revealed and is drawn in conjecturally below the base of the Fourth Grit feature. The primary surveyors obviously regarded the Fourth Grit as a resistant capping to the softer Third Grit, the both being mapped as a single "Middle Grit". The presence of two distinct grits is proven in exposures in Sharnberry Gill and Spurlswood Gill to the east. It is of course possible that the Fourth Grit may have transgressed down onto the Middle Grit here and elsewhere, but in the absence of conclusive evidence it is assumed that the two grits are distinct.

On Raven Hills, south of the north west - south east fault from Lodge Sike, the downthrown Middle Grit forms a brief feature above the First Grit. A single exposure of coarse pebbly grit (968276) confirms the identity of the feature.

North of Monk's Moor, three more Middle Grit outliers occur on the high moorlands above the eastern slopes of Great Eggles Hope. Harnisha Hill is capped by a prominent Fourth Grit feature which preserves the Middle Grit. Below this grit scar another feature marks the top of the First Grit, with sandy micaceous buff shales cropping out in the south west corner, while to the north east, on the Union and Rural District Boundary, some loose grey shales occur above the base of the feature. No exposures of the Middle Grit occur, but it may be anything up to 30 feet in thickness.

East of Harnisha Hill a bean-shaped double feature (Three Laws) occurs, the lower feature corresponding to the lower Harnisha Hill feature, and being taken as the top of the First Grit. Above this, the Second feature is very unlike the flat-topped scar feature of Harnisha Hill, and marks the base of the Middle Grit, which has weathered back more rapidly in the absence of a protective Fourth Grit cover, leaving a broader shale feature below. East of this rounded Middle Grit prominence, a smaller, similar hill feature occurs, both being underlain by the same, continuous shale feature. There are no in situ grit exposures, but some loose blocks of coarse grit occur, which may be relics of the Fourth Grit.

To the east, the Middle Grit forms the Pawlaw Pike feature (008321), and that running from Long Man (996318) to Jack Scars End. The latter is truncated on the south by the Little Eggleshope Vein. A single exposure of course grit occurs. South of the vein the base of the Fourth Grit is thrown down to a level just above the base of the Middle Grit on the north. The Fourth Grit forms the bold feature of Jack Scars. Below this the Middle Grit gives rise to a fairly prominent feature, truncated on the north, of course, by the Little Eggleshope Vein. Some coarse grit is exposed in the southern extremity of the triangular shaped feature. The top of the grit is mapped as a conjectural line below the Fourth Grit scar.

The final outlier is situated below White Hill, between Great and Little Eggles Hope. The hill is capped by the Fourth Grit, while the top of the Middle Grit is outlined by a shale feature 10 to 15 feet high. The grit itself forms a feature only in the south west, where it is interrupted by the East Rake Vein and upthrown 10 feet to the south. Elsewhere the base is a conjectural line. To the north the grit is faulted out by the Flake Brig Vein (up 100 feet to the north).

<u>The country east of Little Eggleshope Beck/Eggleston Burn</u>:- Down the eastern slopes of lower Little Eggleshope Beck and Eggleston Burn, the Middle Grit gives rise to a not very conspicuous feature below Islington Hill, and above the prominent First Grit - Grindstone Sill feature of Brown Dodd (see pl. 9 , p. 245). Apart from these short-lived features the position of the base of the grit is uncertain. The top of the grit is drawn in relative to the prominent scar feature of the Fourth Grit below Millstone Rigg and on Water Crag. Nothing is seen either of the grit or succeeding beds below the Fourth Grit. In fact there is no evidence here upon which one can criticize the primary surveyors' interpretation which resulted in the mapping of two grits above the First Grit (the Third and Fourth being mapped as a single Middle Grit), instead of three as mapped in the present survey.

When the Middle Grit is followed eastwards along Sharnberry Overflow, however, evidence disproving the over simplified primary surveyors' interpretation is encountered. The base of the grit can be mapped with reasonable accuracy downstream until it rises onto the higher ground above the gill. On the northern bank, two exposures of sandy, micaceous shale occur (999308 and

004308) which first reveal the presence of beds between the Third and Fourth Grits. On the southern bank (000306), the Middle Grit, exposed as a typically loosely compacted, limonite-stained, coarse grit, is capped by:

		Ft.	Ins.
Sandstone grading down into sandy, grey shale, which in turn grades down into soft, friable, grey shale	3 Ft. to	4 -	0
Coal.		1 -	0
Ganistroid sandstone.	3 Ft. to	4 -	0

The upper sandstone is possibly the base of the Fourth Grit, or occurs just below it, as the latter can be traced thus far from below Islington Hill. The grit is seen to have an apparent dip of 21° south 170 yards downstream, but in view of the lithological nature of the grit, the reading is not reliable.

In the northern bank, the base of the grit is traced up to the plateau above the gill, where it forms a feature running north eastwards towards Sharnberry High Level (011314) before swinging eastwards beyond Nanny Sike. Thence, after a gap of approximately 330 yards, it can be mapped around the spur and north westwards, overlooking South Grain Beck, as far as the Sharnberry Vein, where it is upthrown to the north west. The top of the grit is drawn in below the Fourth Grit feature throughout its length, but in the south bank tributary of South Grain Beck, shaly buff sandstone grading down into sandy grey and buff shale, totalling 4 feet, is exposed below the Fourth Grit. The Third Grit itself is only exposed in the stream west of Nanny Sike, as a coarse grained, limonite- stained, loosely compacted grit.

South of Sharnberry Gill, on Sharnberry Flat, the Middle Grit gives rise to a relatively weak, feature, which continues southwards in a sinuous course across Morton Shield to the headwaters of Cloudlam Beck, and then eastwards to the head of Acton Beck. Beyond this it can be mapped along the forest rides of Pennington Rigg. The grit is exposed in Cloudlam Beck and one of its tributaries, retaining its typical, coarse grained, loosely consolidated, limonite-stained character, with foreset directions indicating a west north westerly source in Cloudlam Beck. The top of the grit and overlying beds below the Fourth Grit are unexposed, so that the upper limit is drawn in relative to the Fourth Grit feature. Below High Acton Currick (031280) and Low Acton Currick (036283), however, a small feature does occur, running in an east north easterly direction above the Middle Grit. No in situ exposures occur within this feature, but its formation may be due to the sandstone seen between the Third and Fourth Grits elsewhere (particularly in Spurlswood Gill, see p. 305). The basal feature of the Middle Grit can be mapped around Pennington Rigg to the forestry road running along the top of the ridge, beyond which it is lost sight of in the plantation. The Knotts Fault runs south of the road downthrowing the grit to the south. A secondary feature occurs within the grit on Pennington Rigg, but the reason for its development is not certain; the top of the grit is better consolidated in some localities (e.g. in parts of Spurlswood Beck) and this may account for it. The grit is exposed in one of the rides (039286) and on the forestry road (048288), displaying typical Middle Grit lithology in both localities.

West of the Black Hill Fault, the Middle Grit once more forms a feature, fairly bold in this instance, where it is well protected by the Fourth Grit of Black Hill. On the west it is interrupted by the north north east - south south west fault previously mentioned (p.294) which lets the grit down to the west. A feature arises on the western end of the hill but dies out eastwards on the northern flanks, and disappears beneath drift on the southern flanks. The top of the grit is conjectural, its mapped position being based upon the overlying Fourth Grit feature. East of the Black Hill Fault, the downthrown Middle Grit forms a feature overlooking South Grain Beck, running roughly east-west for approximately 1,200 yards before dying out as it swings southwards across the plateau top. On the south, below Brown Law, it can be picked up once more along the forest rides until blanketed by a patch of drift. The top of the grit is marked by an intermittent feature north and east of the Fourth Grit feature on Brown Law. Numerous springs arise below the Fourth Grit on the eastern and south eastern edges of the feature, presumably on shales between the two grits. The Middle Grit is only exposed within the feature overlooking South Grain Beck (044312), where some coarse grained, current-bedded grit crops out.

<u>The Spurlswood Gill-Eggleston district:-</u> The Knotts Fault crosses Quarter Burn 600 yards west of the latters' confluence with Spurlswood Beck. North west of the fault, on the upthrow side, the top few feet of the Middle Grit crop out in the stream bed as a coarse grained, limonite-stained, loosely consolidated grit. Nothing is exposed between this and the overlying Fourth Grit. Near the confluence of Quarter Burn and Spurlswood Gill the grit is exposed in both streams. In Quarter Burn, the soft limonite-stained coarse grit is capped by the following

Plate 14.

A. The Middle Grit, Quarter Burn. The lower part of the section shows the typical rotted condition of the grit while the upper part appears more compact than it actually is.

B. A section in Quarter Burn showing beds from the top of the Middle Grit to the top of the Fourth Grit. The top of the former can be seen a few feet above stream level; the thin (two feet) sandstone about fourteen feet above is the tough quartzite which appears to persist to the east. The Fourth Grit at the top of the section thins rapidly to the east(right) and displays an unusually rotted lithology more typical of the Middle Grit.

succession:

	Ft.	Ins.
Coarse grit (the Fourth Grit)		
Shaly sandstone grading down into sandy micaceous shale, in turn passing down into- fine grained, dark grey shale	26	0
Grey - buff quartzite.	2	3
Sandy, grey and buff shale, grading down into - soft grey shale.	6	0
Black, carbonaceous shale with coal smuts.	1	8
Soft grey shale grading down into sandy micaceous shale.	6	0

The coaly shale is probably equivalent to the 1 foot coal seen in the Sharnberry Overflow Channel, but no underlying ganister or ganisteroid sandstone is present. The beds dip east at 8° in the stream bed. The grit outcrops in both banks of the burn, and just upstream from the confluence, the top 5 to 10 feet of the grit is more compact (see pl.14A,B, p.304). In the northern bank of Spurlswood Beck (or Gill), near the confluence, up to 25 feet of coarse grit is succeeded by:

	Ft.	Ins.
Ganister.	0	3
Fine grained, buff, shaly sandstone.	4	0
Sandy grey shale.	2	0
Black, carbonaceous shale with coal smuts.	0	4
Coal.	0	1
Soft, sandy, micaceous ganisteroid sandstone with plants, grading down into -	3	0
Sandy grey shale.	3	0

The variability of the succession is seen by comparing these two successions, situated less than 200 yards apart. Much of the succession up to and including the Fifth Grit is seen in the south bank of Spurlswood Beck near this point. 22 feet of the Middle Grit is exposed as a coarse, limonite-stained (typically yellow and orange in colour), ill-compacted grit, capped by

16 feet of black shale. A gap of approximately 50 to 60 feet is followed by a sandstone which may represent the top of the Fourth Grit. No coal or ganister is seen above the grit in this exposure.

140 yards downstream from the confluence the base of the Middle Grit rises above stream level, and the full thickness of 40 to 45 feet is exposed in the north bank. Downstream, the grit is intermittently exposed in both banks for 1,400 yards, with outcrops of 30 feet and 40 feet in the south bank, 300 yards and 500 yards, downstream respectively. The exposures are characteristic with loosely cemented, coarse, yellow and orange grit standing out prominently against the green and brown of the vegetation. Springs, with a high iron content in the water, tend to rise at the base of both the Middle and Fourth Grits. 500 yards east of the confluence, high up in the north bank, the following succession is revealed below the Fourth Grit:-

		Ft.		Ins.
Coal.		0	-	2
Ganistroid sandstone.	3 Ft. to	4	-	0
Shaly, micaceous, buff sandstone grading down into - Sandy, micaceous, buff-grey shale		4	-	0

The contact of these beds with the underlying grit is not seen, but the coal probably represents that seen upstream and in Sharnberry Overflow Channel, and the ganister is no doubt equivalent to the one below the Sharnberry coal. A further 150 yards to the east, the 2 feet quartzite (No. 210) crops out once more; this bed may quite possibly be responsible for the feature overlying the Middle Grit below High and Low Acton Curricks (see p. 302). Directly opposite, in the south bank, 9 to 10 feet of sandy, grey shale outcrop above 40 feet of coarse grit belonging to the Middle Grit.

The grit is next exposed in Thorny Cleugh and its tributary, and also in another south bank tributary of Spurlswood Beck, to the west. It retains its characteristic lithology, and its base crops out at the confluence of Thorny Cleugh with its tributary. In the latter stream, the grit is succeeded, after a gap of a few feet, by the following:-

	Ft.	Ins.
Coarse grit (the Fourth Grit)		
Poor ganister.	2	8
Sandy grey shale.	10	0
Flaggy, medium to coarse grained micaceous buff sandstone passing laterally into sandy shale.	6	0
Sandy grey shale.		

The ganister is probably equivalent to that met with in Spurlswood Gill and Sharnberry Overflow. These beds dip due west at 13°. The base of the grit can be traced around to the first of the north north west - south south east trough faults (see p. 288), with exposures of coarse grit in a tributary to the east, and immediately west of the fault, where 11 feet of medium grained grit crop out. The top of the grit is conjectured as it is for practically the whole of its course along Spurlswood Gill. Between the two trough faults the base is marked by an outcrop of coarse, pebbly, yellow grit above 20 feet of shales.

The grit is further exposed in Smithy Hirst Sike, the north bank tributary of Spurlswood Beck. The top of the grit, coarse, limonite-stained, and micaceous, is followed by some grey and buff micaceous shales, 300 yards upstream from the confluence, immediately east of the western trough fault. Approximately

15 to 20 feet of the coarse grit crop out in the stream bed west of the fault, presenting a typically smooth stream profile. Various gaps occur in the overlying succession, but 4 feet of interbedded sandy, micaceous, shale, and fine grained micaceous sandstones occur close above, followed upstream by 6 feet of sandy, micaceous shale with plants, and a 1 foot ganister. This latter probably corresponds to the ganister or ganistroid sandstone seen elsewhere. Close above, the Fourth Grit outcrops in the stream.

East of the trough faults the grit is concealed until we reach Rowley Beck and its tributary The Springs, in the southern banks of Spurlswood Gill. Here, 30 to 40 feet of coarse pebbly grit (No. 214) overlie some shales, but nothing of the succeeding beds is seen apart from the Fourth Grit. Seavy Sike offers the next glimpse of the grit, where it is but poorly exposed. Beyond this it is lost sight of in Hamsterley Forest until a feature marking its base makes an appearance above Blackling Hole. This enables one to trace the grit accurately to Greenless, where exposure is once more good. 25 to 30 feet of typical Middle Grit crop out in the stream bed and cliff exposures in both banks. Above the grit, grey micaceous shale with thin sandstone lenses containing plant remains occur, grading up into sandy buff shale. A total of at least 30 feet crops out in the stream bed. The top and base of the grit are marked by features which can be mapped in the forest rides downstream. The only exposure of grit occurs in the Forestry Commission road from The Grove (067300) to the Woodlands - Hamsterley road. It is a typical medium to coarse grained grit (No. 229). The base of the Fourth Grit can likewise be mapped as a feature by tracing it from one ride to the next, but nothing is seen of the intervening strata.

In the left bank of Spurlswood Gill, the situation is very similar, with exposures of typical Middle Grit in the various tributaries, with foreset directions suggesting a north easterly source in the stream joining Spurlswood Beck between Blackling Hole and Greenless Hole. The beds are of course upfaulted 1 mile downstream from Greenless Hole by the north east - south west Knotts Fault.

Above Nemour, a typical Middle Grit feature, not very bold, occurs above the First Grit. The top of the grit is marked by a 15 feet high feature, presumably containing shale and perhaps sandstone, below the Fourth Grit. The 'V' shaped outcrop is terminated on the north and the east by the curved fault running from Stobgreen to Knotts. The north east - south west arm of the feature forms a perfect dip slope, dipping north north easterly towards the fault. North of the fault, the base of the downthrown grit is briefly outlined by a feature for 300 yards, beyond which it is concealed beneath the Blackton Beck drift. The grit has been mapped conjecturally as a 'V' shaped outcrop around Blackton Head.

In the Stobgreen area, south of the Northern Eggleston Fault, the downthrown grit crops out 100 yards north east of Death Nook (018243) with 2 feet 6 inches of medium grained, haematite stained grit (No. 286) dipping north east at 35°. The base of the grit is drawn in relative to the feature marking the top of the Second Grit, which peters out a short distance to the west. The top of the grit is outlined by a feature where the steeply dipping grit dips below overlying shales (presumably) and the Fourth Grit, which is also feature forming. The Middle Grit feature runs from the northern boundary wall of Stobgreen Plantation a distance

Plate 15.

A. The Fourth Grit scar of Monks viewed from the north west.

B. A close-up of the above showing the massive character of the grit.

of 760 yards to the east south east, beyond which it disappears beneath a patch of drift. To the west, the feature is lost sight of, presumably where the beds dip steeply towards the Northern Eggleston Fault. The grit is also fault bounded on the east where the north west - south east fault between the Northern Eggleston and Redmire Gill Faults lets it down to the north east. The downthrown grit forms a feature near the 1,250 feet contour, with two exposures of coarse, current-bedded, buff grit (032238 and 034238). 4 feet of grit crop out in the latter of these 2 exposures, dipping north north east at 30°. Approximately 500 yards east of the north west - south east fault, another fault, running in a north north west - south south east direction, throws the grit down to the east once more, beyond which it is not exposed in the area mapped.

<u>The Fourth Grit and the beds up to the base of the Fifth Grit.</u>

<u>The North Western Outliers</u>:- Monk's Moor culminates in Monks, a bold grit scar feature, roughly rectangular in outline, the flat upper surface of which dips eastwards at 3 or 4°. It is covered with peat deposits which support a thick growth of heather. The grit is massive, coarse grained, cream in colour, from 10 to 15 feet thick, and breaks off in huge rectangular blocks (see pl.15A and 15B, p.309). No contact with underlying beds is seen, so that the exposed grit may not represent its full thickness.

To the north east, White Hill, above Middle End, is also capped by the Fourth Grit, but the feature is not bold, and no scar outcrops occur, presumably because the grit is largely eroded, with only a few feet remaining. Further north, on

Harnisha Hill, the characteristic flat-topped grit scar feature is once more boldly developed. The grit is coarse grained, and massive, with numerous very large grit blocks scattered around the feature, which is peat covered and roughly square in outline. Here again the base is not revealed, but approximately 15 feet of grit is exposed.

Jack Scars, to the east, is a triangular grit scar feature with all the characteristics of the foregoing typical Fourth Grit outcrops. It is terminated on the north by the Little Eggleshope Vein, while a small east - west fault lets the grit down a few feet at the southern apex of the triangle to form an independent nose-like grit scar feature. Almost horizontal slickensides occur in the grit on the south west limit of this latter feature (not in the plane of the east - west fault.) The base of the feature has been taken as the base of the grit once more, but no contact with underlying beds is seen.

<u>The country east of Little Eggleshope Beck - Eggleston Burn</u>:- The Fourth Grit is perhaps best exposed on the eastern slopes of Little Eggleshope Beck - Eggleston Burn. A prominent feature runs along the greater part of the valley, following a sinuous north - south course. Between Islington Hill and Millstone Rigg, where the overlying beds are removed, a continuous grit scar feature runs southwards for over 1,200 yards, forming Wheel Crag. The grit is medium to coarse grained (No. 147), massive, and up to 15 feet thick, weathering white from a more normal buff colour. Below the protecting Fifth Grit of Islington Hill and Millstone Rigg, no real scar feature is developed, but the Fourth Grit feature is littered, below Millstone Rigg, with large blocks

of coarse grit. In situ grit exposures do occur however, with coarse to very coarse, buff grit up to 10 feet thick being exposed.

At Knotts two faults interrupt the grit, the north east - south west fault from Lodge Sike, and the Knotts Fault itself. South of the former, the downthrown grit feature swings south westwards for a short distance before turning eastwards along the Knotts Fault. Good exposures of the grit and succeeding beds occur in two old quarries. In one (997263) at Knotts Hole, the following succession is exposed:-

	Ft.	Ins.
Baked shale.		
Fine grained, flaggy white sandstone becoming more massive towards the top, and grading down into a siltstone.	18	0
Splintery, baked shale.	4	0
Limonite-stained, grey sandstone.	0	6
Baked shale.	2	0
Coarse grit (No. 126).	23	0

presumably?

The shale has been metamorphosed by the Whin dyke which follows the course of the Knotts Fault, but which is not exposed here. The thickness of the grit suggests that the 15 feet or so exposed in the grit scars to the north, may not in fact be the full thickness of the grit, the base of which is not seen. The top of the grit is feature-marked between the two faults. Immediately north of the north west - south east fault the top of the grit is outlined by a shale feature below the Fifth Grit, but beyond this it is drawn in relative to the overlying Fifth Grit, until the latter swings eastwards to form Ever Rigg, where the shale feature is once more developed.

Between Islington Hill and Ever Rigg, the Fourth Grit forms a flat-topped plateau covered with peat. At the head of

Cloudlam Beck, on the east, the grit gives rise to a grit scar, with massive, medium to coarse grit cropping out. The feature can be traced northwards to the southern bank of Sharnberry Gill. Westwards from here along Sharnberry Gill, the base of the grit is marked by a far less prominent feature for approximately 300 yards, and then is mapped with reasonable confidence along the valley top to the exposure referred to previously (p. 301) as revealing a 1 foot coal surmounting the Middle Grit. The sandstone surmounting the succession in this exposure may possibly represent the base of the Fourth Grit, or a sandstone below it. West of this point the grit can be traced around Islington Hill. The position of the top of the grit is fixed by a shale feature below the Fifth Grit on the northern, eastern, and southern flanks of Islington Hill, but not on the western flank, where it is conjectural.

On the northern slopes of Ever Rigg both the top and base of the grit are marked by features. The latter feature runs eastwards as far as Neighbour Moor Head where it turns southwards to the head of Acton Beck, then eastwards for 600 yards and finally southwards to Knotts Fault. The shale feature outlining the upper limit of the grit follows a similar course. Of the beds between the Fourth and Fifth Grits, nothing is seen until Ever Pools, an overflow channel containing three small, but apparently deep pools (see p. 424). At the south eastern end of this channel, the following succession is exposed:-

		Ft.	Ins.
Fine grained, grey, baked shale.		35	0
Fine grained, massive, buff sandstone possibly) the Fourth Grit recrystallized.)	up to	10	0

The Knotts Fault runs a short distance to the south, and the shales are undoubtedly metamorphosed by the Whin Dyke which follows the course of the fault, though it is not exposed. The Fifth Grit feature marking the top of the intervening shales runs in a rough westerly direction to the overflow chennel on Millstone Rigg (999273), and then southwards almost to the Knotts Fault. The shale feature on top of the Fourth Grit follows a sub-parallel course, with the Fourth Grit forming a broad, flat, peat covered moorland tract below. The base of the grit is once more marked by a feature, with some scar exposures of course grit, 'V' - ing upstream and crossing the bed of Quarter Burn 270 yards upstream from the Knotts Fault.

North of Sharnberry Gill, the high ground between the latter and South Grain Beck is capped by the Fourth Grit south east of Sharnberry Vein. To the north west it is upthrown and preserved only in the outliers previously described. The grit forms a feature which can be mapped with reasonable confidence, but which does not give rise to grit scars. This may be due to the thick peat cover, or possibly to a more advanced state of erosion (as on White Hill - see p. 309), or yet again to a less compact grit than is normally met with. This latter possibility is supported by an exposure of soft, very coarse, cream grit near the base of the feature where it is cut by the tributary of Nanny Sike, approximately 80 yards north east of Sharnberry High Level. On the other hand, in the south bank tributary of South Grain Beck, the grit is exposed as a flaggy (current-bedded,) very coarse, limonite-stained grit, of a more compact nature than the previous outcrop. It is sufficiently compact to reveal jointing in two directions, north 80° west, and north 11° west. It is possible that the exposure of soft grit belongs to the underlying Middle

Grit; it is the only exposure in the vicinity, and the feature is naturally vague when 'V'-ing into the stream, so that the base of the feature may be incorrectly mapped here and may occur above the exposure.

To the south east, Black Hill is capped by the Fourth Grit, forming a double feature. The lower feature is approximately 15 feet high, the upper, 5 to 6 feet high, but fading out on the north. An old quarry (035304) reveals some medium to coarse grained grit in the upper feature. The lower feature is terminated on the east by the Black Hill Fault. On the west the feature is closed but practically borders the north north east - south south west fault on Black Hill. This latter throws the Fourth Grit down to the west, bringing the base of the grit on the west, level with the base of the Middle Grit on the east, i.e. approximately 60 feet. Loose blocks of coarse grit abound on the feature. This also contains a subsidiary feature. East of the Black Hill Fault, the downthrown Fourth Grit forms a prominent, roughly semicircular feature with loose grit blocks, but no in situ exposures. The secondary feature makes a brief appearance in two places, on the north, and on the east.

<u>The Spurlswood Beck - Eggleston area</u>:- On Grey Carrs, north of Stobgreen Plantation, the Fourth Grit gives rise to a 'V'-shaped feature terminated on the north east by the curved Grey Carrs Fault. The feature is approximately 10 to 15 feet high, and dips to the north east. Six
6 feet of massive, fine grained sandstone grading down into coarse grit (No. 224) are exposed, jointed in two directions north 44° east, and north 46° west. A second grit feature follows close above. This has been taken as the Fifth Grit, but it may be equivalent to the subsidiary feature

within the Fourth Grit seen on Black Hill. If this is the Fifth Grit, then the intervening beds can be no more than 10 feet thick.

North east of the fault, the downthrown grit feature runs north eastwards for nearly 500 yards before disappearing beneath the Blackton Beck drift. The feature is littered with huge blocks of massive, current bedded, coarse grit (No. 223). Beyond this it is conjectural. The top of the grit has been mapped at the base of a shale feature which can be followed north eastwards and then northwards to Spurlswood Beck.

Good exposures of the grit exist in Spurlswood Overflow and Spurlswood Gill. Outcrops of massive, coarse grained buff grit (No. 205), becoming fine grained towards the top (No. 204) occur in the overflow and gill, with current bedding dips suggesting a south westerly source at the junction of the overflow with Spurlswood Beck (014262). In the latter locality the grit is jointed in two directions north 50° east, and north 15° west. The base of the grit crosses the stream bed and the bottom of the overflow near here, and can be traced with a reasonable degree of accuracy downstream through intermittent scar exposures, and the disused Spurlswood Quarry (014265). Approximately 130 yards downstream from the confluence dips of up to 10° to the south east and north west, towards each other, suggest a small fault running north east - south west along a depression in the left bank, but no actual fracture is seen in the grit scar. The top of the grit can be mapped with confidence, with exposures downstream serving as fix points. Near the quarry an exposure of loosely compacted, yellow and orange grit is reminiscent of the Middle Grit. The grit scar extends intermittently in both banks as far as the Spurlswood Beck - Quarter Burn confluences. In the left bank the bold grit-scar swings around below Slate Ledge into Quarter Burn, the grit flooring the stream for nearly 100 yards from a point just over 300 yards upstream from the confluence. Approximately 260 yards upstream from the final exposure of the grit, some black shales crop out in the stream, while 120 yards north, in the tributary stream of the burn, 10 feet of dark grey, micaceous shale underlie the Fifth Grit immediately south of the Knotts Fault.

The topmost exposures of the grit in the burn reveal a fine to medium grained buff sandstone or grit, but downstream, up to 5 feet of massive coarse grit cap a more loosely cemented, coarse, yellowish grit, lithologically identical with the Middle Grit, the whole totalling 30 to 35 feet in thickness. This grit was at first thought to be a fault repetition of the Middle Grit exposed downstream, but structural considerations rule this out, as underlying shale and sandstone beds can be traced uninterruptedly downstream to a point where they overlie the Middle Grit. This loose grit appears to thin rapidly downstream (see pl.14B, p.304), while some loose blocks of coarse, massive, compact grit testify to the continued presence of the more typical lithology, if somewhate attenuated. Downstream more normal conditions appear once more.

Directly south, in the right bank of Spurlswood Gill, the grit proper is not seen in a comparatively well exposed section. Above the Middle Grit, 16 feet of shale are succeeded by a gap of at least 50 feet, consisting of loose shale and rubble, in the steep bank. Some fine grained sandstone may possibly represent the top of the Fourth Grit, but no thick grit is developed; any such development would undoubtedly be seen. Above this sandstone, 11 feet of sandy, micaceous, grey shale are capped by a 12 feet fine grained, ganistroid sandstone (which also may represent the grit horizon), and 46 feet of shale below the Fifth Grit. Both to the east and west of this exposure, the massive Fourth Grit can be seen, so that a north-south belt (from Quarter Burn to Spurlswood Gill at least) of approximately 100 yards or more in width exists in this locality, with very poor grit development at this horizon. In Quarter Burn the attenuation can be seen eastwards for a limited distance, as previously described. Faulting, the only other explanation can be discounted on the fact that both overlying and underlying beds are undisturbed.

Downstream, in both banks, exposures of massive, compact, medium to very coarse grained grit, showing a tendancy to rotten weathering in places, fascilitate accurate mapping of the Fourth Grit. In the north bank a feature with some loose shale runs north eastwards above the gill for over 500 yards before disappearing beneath drift. This marks the top of the grit. The beds within this feature are unexposed, but 10 feet of shales below the overlying Fifth Grit crop out in the Quarter Burn tributary (see p.316).

In the south bank of Spurlswood Gill, exposures of 17 feet of buff, limonite-stained, sandy shales occur below the Fifth Grit in Thrindle Hills. These shales form a relatively bold feature running in an irregular semicircle across Woodland Fell from Thrindle Hills (where drift mounds obscure the true run of the feature) almost to Greenless. The base of the feature, which is from 30 to 40 feet high, was taken as marking the top of the

Middle Grit by the primary surveyors (the Fourth Grit in the present survey), which seems perfectly reasonable, for Woolly Gill, at the head of Rowley Beck, reveals at least 10 feet of black fine grained shale. Exposures of shale and thin sandstones in Rowley Beck and other streams prove this to be incorrect however.

The base of the Fourth Grit is delineated by a fairly poor feature with some loose grit blocks, which can be traced from the almost north-south parish boundary to Rowley Beck and The Springs with minor interruptions. In Thorny Cleugh 6 feet of massive, coarse grit is all that is seen of the horizon and overlying beds, and this probably represents its full thickness. In the stream to the east a few feet of medium grained grit overlie a ganister, shales and sandstones, dipping west at 13°, while 70 yards upstream a soft, fine grained, grey siltstone exposure offers the first definite evidence that the weakness of the feature does in fact reflect a poor grit development rather than an unconsolidated easily eroded set of beds horizon, extending to the base of the shale feature. ? The basal feature can be traced eastwards around Rowley Ridge to Rowley Beck, after interruptions by the north north west - south south east trough faults previously mentioned (p. 288). In Rowley Beck some medium grained, buff sandstone represents the Fourth Grit, with some buff, sandy shale outcropping 200 yards upstream. A further 400 yards upstream, an 18 inches micaceous, buff siltstone overlies a 9 inches micaceous sandstone and micaceous, grey and buff siltstone dipping east north east at 4°. The beds are jointed in two directions, north 34° east, and north 60° west. These facts further confirm the attenuation of the grit on Woodland Fell.

In The Springs, a tributary of Rowley Beck, 2 or 3 feet of buff grit passing up into a micaceous, shaly sandstone are all that can be seen below the Woodlands Fell shale feature. To the north east, in Seavy Sike, 4 to 5 feet of coarse, limonite-stained grit grade up into fine grained sandstone, which is jointed in two directions, north 34° east, and north 66° west. Some medium grained buff sandstone crops out a few yards upstream, but nothing else below the shale feature. The next exposure is in Greenless, where a coarse, current-bedded, limonite-stained grit floors the stream for over 120 yards, and crops out in the east bank as up to 5 feet (exposed) of medium to coarse grained, buff grit (No.216) The stream exposure probably amounts to at least 10 feet. A fairly prominent feature runs northwards from the stream to the Union and Rural District Boundary, beyond which it can be mapped down Spurlswood Gill in the forest rides. It develops a secondary feature in the plantation, probably due to differential compaction, as seen in Spurlswood Gill to the west.

The overlying shale feature is still fairly prominent, and in the forestry road to The Grove (065289) at least 10 feet of black, limonite-stained, shale with ironstone nodules are exposed.

In the northern bank of Spurlswood Gill the position of the grit can be mapped with reasonable accuracy for almost a mile east of the Quarter Burn confluence beyond which it is lost sight of until Smithy Hirst Sike. The top of the grit is largely masked by drift so that its thickness is not known. In Smithy Hirst Sike it is seen to occupy the stream bed for nearly 200 yards, as a micaceous grit which is medium grained and somewhat shaly at the base, but coarser grained towards the top. Its thickness is anything up to 30 feet, indicating that the attenuation seen on Woodland Fell is not easterly, but southerly. The base of the grit in the sike is revealed close above a ganister (as in the stream east of Thorny Cleugh) so that the position of its base can be fixed with reasonable certainty although not actually seen. The top of the grit cannot be so fixed however, and has been taken some distance upstream from the final exposure, which occurs on the flat-topped northern banks of Spurlswood Gill. To the east, the trough faults let the grit down between then, but it is not exposed. Thence downstream the base is only occasionally marked by a feature, the afforestion and drift cover obscuring it almost completely. There are no exposures, and the base is mapped relative to the Middle Grit. The overlying shale feature can be accurately mapped along Pennington Rake to the forestry boundary, beyond which it can be located along only two rides, one of which lies immediately south of the Knotts Fault. Nothing is seen either of the grit, or of the overlying beds below the Fifth Grit feature.

Finally, north of Death Nook (018242), the Fourth Grit forms a double feature, marking the base and the top of the grit in this steeply dipping section of strata. Some fine grained, slightly micaceous, buff quartzite crops out near the top of the horizon. Nothing else is seen south of the Northern Eggleston Fault and the north west - south east Fault. East of the latter the downthrown grit forms a bold double feature (littered with large blocks of coarse grit) which runs eastwards for almost 1,200 yards before being downthrown yet again by the north north west - south south east fault mentioned previously (p. 309). Beyond this fault the feature runs eastwards to the Woodlands road, where it is lost sight of, probably due to the drift cover. No in situ exposures occur, and nothing is seen of the succeeding beds below the Fifth Grit feature.

The Fifth Grit.

This grit was mapped by the primary surveyors as their Third and topmost "Millstone Grit", with succeeding beds being placed in the Coal Measures. It has been retained as the uppermost member of the "Millstone Grit", forming the Fifth Grit of that series.

Islington Hill is surmounted by the Fifth Grit, which forms an egg-shaped feature. Some very large blocks of massive coarse grit occur along the western side of the feature. To the south, the largest mapped outcrop of the grit caps the high moorland of Eggleston Common, forming Ever Rigg. The western end of this outcrop forms the grit scar feature of Millstone Rigg (see pl. 9 p.245) which contains exposures of fine to medium grained, white weathering buff sandstone (No. 138). It runs southwards as far as the Knotts Fault which it skirts eastwards for approximately 350 yards before swinging northwards to the Millstone Rigg Overflow channel (999273). From here it runs eastwards to Ever Pools (021277). East of Ever Pools no feature is seen on the deep-ploughed Forestry Commission land, but the base of the Fifth Grit has been drawn in conjecturally. No exposure of the Grit is seen, but some loose flags of medium grained sandstone occur in the overflow. At the northern end of the Ever Pools overflow the feature can be once more picked up and followed to Millstone Rigg. The flat plateau top of Ever Rigg is covered with peat and there are no exposures of the Fifth Grit apart from those on Millstone Rigg. These latter exposures reveal up to 4 feet or so only, so that the full thickness is unknown. The plateau surface falls from a height of 1,590 feet O.D. in the west (001277) to 1,439 feet O.D. in the east near Ever Pools, 151 feet in 1⅛ miles, or approximately 1 in 40.

South of the Knotts Fault, the Grit is downthrown at least 100 feet. Immediately south of the fault, in the left bank of the small tributary stream of Quarter Burn, 10 feet of flaggy, medium grained, mottled sandstone or grit (No. 207) belonging to the Fifth Grit are exposed; probably by no means the whole thickness, but forming one of the better exposures of the Fifth Grit in this area. Eastwards, the Fifth Grit forms a feature running over 1,000 yards before disappearing beneath drift, beyond which, the base is mapped conjecturally until we reach Pennington Rake. South of Quarter Burn the grit forms Slate Ledge, its base being traced by a fairly weak feature. Some exposures of medium grained sandstone, and fine grained, white weathering sandstone (No. 203) occur, the latter appearing at a higher level and confirming an impression that the Fifth Grit is probably fine grained at the top, but slightly coarser nearer the base.

South of Spurlswood Gill a feature can be mapped from above the Spurlswood Overflow - Spurlswood Beck junction, through Thrindle Hills (where the run is confused by drift mounds) and thence across Woodland Fell to Woolly Gill. The base of the feature is marked, east of the parish boundary, by a line of springs which give rise to Thorny Cleugh and its associated streams. Exposure along this feature is very poor, being confined to some loose flags of medium to coarse grained grit above shales west of Thrindle Hills (020266), and 2 feet 4 inches of micaceous sandstone above shales in two old quarries (037252 and 033251), (the former of which worked a member of the Cleveland was worked

Dyke system) at the head of Woolly Gill, and to the west. The top of the grit has been taken at the base of a weak feature (probably shales) which runs south eastwards for 140 yards from above Thrindle Hills.

South westwards from Spurlswood Gill, both the top and bottom of the Grit are conjectured, apart from a 300 yard long feature marking the top on Grey Carrs. Immediately south west of the Grey Carrs Fault, a 'V'-shaped feature with very large blocks of medium to coarse grained grit (No. 225) has been taken as the Fifth Grit, rather than a subsidiary feature of the Fourth Grit which lies close below. The feature is 15 feet high.

In Barnard Castle Allotment, to the east, the Fifth Grit crops out east of the north west - south east fault. It gives rise to a scar feature with very large loose blocks of coarse grit, and in situ exposures of 10 to 12 feet of massive, coarse grit (No. 287). The feature can be traced eastwards with intermittent gaps, for 1,200 yards to the second, north north west - south south east fault. One exposure in this feature (032241) reveals 3 feet of coarse grit dipping due north at 7°. The top of the grit is also marked by a short-lived feature where it dips below the Coal Measures.

Beyond the last mentioned fault two features, marking the top and bottom of the grit, can be mapped to the east, the latter running as far as the Woodlands road, the former petering out after 400 yards. Near the road, some old quarries contain loose flags of coarse grit, while a larger quarry to the north (043244) also contains flags of coarse grit and some buff shale. A dip of 30° north north east was shown in this quarry on the Old Series 1 inch Geological Survey map, but there are no in situ exposures there now.

East of Woolly Hills, the position of the grit is conjectural and is drawn in above the shale feature on Woodlands Fell (see p. 317). At the head of Seavy Sike, a few feet of fine to medium grained flaggy buff sandstone crop out in an old gravel pit (055267). To the north east an old quarry 30 yards east of Green Letch Cottage (060271) is now overgrown, but still confirms the presence of the grit. To the north, near Mayland Cottage (061278 a feature can be mapped, with a sandstone exposure 70 yards east of the cottage. This feature can be traced along the forest rides to the north, as far as the forestry road to The Grove, where an old quarry, although overgrown, once more confirms the presence of the Grit. 60 yards to the south east, east of the Hamsterley road, some old quarries reveal 8 to 9 feet of current bedded, medium grained, micaceous, buff grit (No. 233). The top of the grit has not been mapped.

North of Spurlswood Gill, on Pennington Rake, the base of the grit is marked by a feature running north eastwards for 1,100 yards from the eastern trough fault. Beyond this it can be located in two forest rides before the grit is faulted out by the Knotts Fault.

PETROGRAPHIC NOTES.

The "Millstone Grits" are a group of generally coarse to medium grained arenaceous beds which may be classed as subgraywackes in the main, but which sometimes tend more towards a quartzite. The degree of coarseness is such as to suggest a closer affinity to graywackes than subgraywackes, but the mineral content overrules this. The "Millstone Grits" are usually strongly current bedded, rather more so than in the typical subgraywackes of Pettijohn (1948, pp. 255-256), and Krumbein and Sloss (1950, pp. 133-134). They are usually buff coloured, sometimes grey. The degree of sorting is poor, to fair, while the individual grains vary from angular to rounded in shape.

Quartz forms the dominant constituent, followed by quartzite and subordinate amounts of felspar, and micaceous minerals set in a liberal clay matrix.

The First Grit (Nos. 92, 136, 170, 182, 191, 192, 194b, 199 226, 284, 285, 296). The First Grit is generally a current bedded, coarse grained grit, (see pp. 78-79) with grains of up to 2 mms. in diameter, but may be medium grained (grains up to 0.75 mm., but averaging 0.25 mm. to 0.5 mm. in diameter), or even fine grained (grains less than 0.25 mm diameter. The grains vary from angular to rounded in form. It is frequently pebbly with pebbles up to 5 mm. in diameter, or more. It is only fairly well sorted. Quartz is the dominant constituent, forming between 60% and 70% of the rock. Much of it shows undulose extinction. Quartzite grains are almost invariably present and may account for as much as 10% of the section (No.266). The felspar content varies from nil (No.136) to 14% (194b) consisting of both plagioclase and orthoclase. It is usually more or less corroded, which frequently renders precise identification difficult if not impossible, but the composition of the plagioclase seems to be largely of the oligoclase-andesine range. Microcline, which Gilligan (1919, pp262) found to be the dominant felspar in the "Millstone Grit" of Yorkshire, is singularly rare, being found only in the specimen from Sharnberry Quarries (No.194b), where a few grains occur. Micaeous minerals are usually present in small quantities, amounting to 4% in one section (199). This generally consists of hydrobiotite, but muscovite and chlorite also occur (Nos. 199, 194b). A matrix of clay minerals occurrs in varying amounts, being more abundant in coarser grits, rangeing from 5% (No. 192) to 25% (Nos 136 and 290) of the section. Heavy minerals are not very varied, the most persistent being zircon and schorlite; rutile also occurs. One schorlite grain of .6 mm. in diameter was found (No. 191). No garnets were located, which Gilligan (1919, pp. 264) records as being by far the most abundant heavy mineral in the Yorkshire Millstone Grits.

Such a rock is by definition (Pettijohn, 1948 pp. 255-257) a subgraywacke, but would appear to disply better current bedding than the typical subgraywacke described by Pettijohn.

<u>The Marine Siltstone</u> (Nos. 215,217, 218, 291) In Spurlswood Gill (Nos. 215, 217, and 218) this is a tough, fine grained, grey siliceous, marine siltstone, with phosphatic <u>Lingula mytiloides</u> shells, and also a fragment of a larger brachiopod replaced by iron pyrites. Microscopically the rock consists of minute angular grains of clear quartz and some small flakes of muscovite and chlorite set in a groundmass of brownish silica. The detrital material forms from 5% to 10% of the rock. The grey colouration of the rock in hand

specimen is due to its content of black carbonaceous mineral, which is liberally scattered through the rock. No. 217 contains globules of clear secondary silica. In Hawke Sike Gill (No.290), detrital grains are much more abundant (up to 80%), consisting mainly of small grains of quartz (up to 0.05 mm. diamter), much of which shows undulose extinction. Quartzite is also present in small quantities. Plagioclase feldspar forms less than 1% of the slide. Muscovite, hydrobiotite and chlorite are fairly abundant, forming approximately 5% of the slide. Clay minerals constitute up to 15% of the slide, and have a greenish brown colouration due possibly to the presence of chlorite. The rock contains a liberal amount of black carbonaceous material, which gives it its grey colour. In hand specimen it is very similar to the Sprlswood Gill band, apart from its higher mica content and slightly coarse nature. Its toughness suggests the presence of a siliceous cement, which is difficult to detect in this section because of the carbonaceous material and clays.

The Second Grit (Nos. 206, 212, 213, 231, 283.) This grit is lithologically very similar the First Grit. Is is current bedded, generally coarse grained, sometimes pebbly, especially at the base (No.213), which has a peculiar lithological structure, consisting of curved, roll shaped prominences.(see pl. 12, p. 289).

These structures correspond closely with those described by R.R. Shrock (1948,pp.156-161) as "Flow Casts". His description of these structures is as follows:- "Soft hydroplastic sediments, if unequally loaded with sand and gravel, yield to the weight of the superincumbent load by flowing. The resulting structure is a layer of coal or shale with the upper surface thrown into asymmetrical drawn out folds and broad, rounded depressions. The overlying sand which can flow because of its large water content, moulds itself to the undulating surface of the mud or organic sediment, so that on compaction the sand layer shows a counterpart of the surface on its underside.... The "rolls", lobate ridges and other raised features thus produced and preserved in the overlying sandstone are here given the designation flow cast because they represent the filling of the negative features produced by the flowage of the soft underlying sediment."

The average grain size is 0.5 mm to 1mm. in diameter, with grain form varying from angular to sub-rounded. Sorting is poor to fair. Quartz is once more the dominant constituent, comprising up to 70% of the sections. Undulose extinction is again a conspicuous feature, while some sections show slightly biaxial interference figures (Nos. 212, 213). Some quartz grains have mantles of secondary silica (No. 212) with the original cores showing far more inclusion than the mantles. Frequently the secondary silica shows signs of transportation indicating second cycles deposition. Felspar, which is usually corroded, amounts to as much as 7% of some sections, and consists of oligoclase and orthoclase, no microcline occurring. Probably much of the clay minerals (which comprise up to 20% of the specimens) represent corroded felspar. Quartzite is prominent, forming 10% of Nos. 212, and 38% of No. 213. This latter percentage is due largely to the presence of pebbles of quartzite up to 2 cms. in diameter. No. 213, a specimen from the base of the grit, is a coarse conglomerate, with pebbles of quartzite mainly, but also of shale (up to 9 mm. diameter) and of felspar (up to 6 mm. diameter). In this section, one quartzite pebble is seen to contain pockets of muscovite flakes up to 0.3 mm. across, as well as chlorite flakes, and rounded zircons. Needles (? rutile) are orientated in three directions. There is also a definite lineation of the quartz within the pebbles. The rounded zircons present an interesting feature, and were obviously incorporated into the quartzite prior to the regional metamorphism of the sediment. Another quartzite pebble has very small biotite inclusions. Clay minerals account for 12% of this section, much of it probably representing decayed felspar. Much of the clays have a greenish colour, due to the presence of chlorite, which can be seen in the corroded felspar. A few flakes of hydrobiotite occur. Patches of limonite and black carbonaceous material are also present. Small zircons were the only heavy minerals detected. This again can be classified as a sub-graywacke.

<u>The Third Grit</u> (Nos. <u>167</u>, <u>214</u>, <u>229</u>) The Third Grit is typically a loosely compacted, coarse grained, yellow or orange coloured grit, "found in a rotted condition..... at a considerable depth" (Dunham 1948 pp.47). Locally it is more compact, forming a current bedded, medium to very coarse grained grit. Degree of roundness is the same as in previous grits. Quartz forms from 60 to 65%, displaying the optical characteristics met with in the quartz content of the lower grits. Quartzite is a more prominent constituent, comprising as much as 14% of the section (No. 167). The felspar content is low, varying from 2% in No. 167 to nil in Nos. 214 and 229. It has probably been almost completely corroded and is represented in the abundant clay mineral matrix, which amounts to as much as 29% (No. 214) in these comparatively compact specimens, and probably greater in the more typical rotted grit. Mica is usually present, forming up to 6% (No. 229) and consisting of hydrobiotite mainly, but also including some muscovite. Small zircons occur, and one grain of schorlite of 0.4 mm. diameter occurs in No. 229. Once

What is this?

more this falls into the subgraywacke category.

The Fourth Grit. (Nos.126, 147, 204, 205, 208, 216, 223, 224a, 288). A medium to very coarse grained grit (0.2mm to 2 mm diameter), generally compact, massive, resistant, and feature forming, but locally a loose 'sand rock' identical with the Middle Grit in its typical development. The grains vary from angular to rounded in outline. Quartz yet again forms the bulk of the rock, normally accounting for between 55% and 65% of the rock. Undulose extinction is a common optical feature. Mantles of secondary silica are present around some of the grains (No. 208). Quartzite is a conspicuous constituent, amounting to between 15% and 23% in most of the sections examined, but only to 5% in No.208, which contains 89% of quartz and 6% clay minerals. No. 208 is in fact a medium grained quartzite. Felspar is a minor component, 3% of corroded felspar in No. 216, being the highest content recorded in the sectioned specimens. Mica is poorly represented, some muscovite and hydrobiotite occurring in small quantities in Nos. 126, 208 and in 216, in which it forms 1% of the slide. Clays form up to 25% of the rock (except for No. 208), being generally more abundant in the coarser grained sections. Limonite occurs in patches interstitially. The heavy mineral suite is poor, both in quantity and variety, a few small zircons being all that were detected.

The rock therefore is generally a subgraywacke but locally becomes a quartzite.

The Fifth Grit. (Nos. 138, 203, 207, 225, 233, 287) A fine to very coarse grained rock, being finer grained at the top. The coarser rock is a subgraywacke consisting of rounded to angular grains up to 1.5 mm. in diameter, set in a clay mineral matrix.

Quartz, with optical properties identical with those of the lower grits, makes up to 70% of the rock. Quartzite, again important, accounts for 14%, while clay minerals occupy over 15% of the sections. Neither felspar nor mica was located in this section, but an occasional mica flake can be seen in the hand specimen of No. 225. Rutile and zircon grains occur. The finer grained part of the rock is a quartzite, consisting of interlocking grains of quartz and some quartzite up to 0.2 mm in diameter. The quartz has the same optical properties as in the coarser grit. No felspar was seen, but mica is present in very small quantities, consisting of small muscovite and hydrobiotite flakes. Clay minerals occur in very small quantities interstitially, with some limonite. Small zircons occur, with two grains of schorlite up to .05 mm. in diameter in No. 203.

THE COAL MEASURES.

These are first encountered capping the Grey Carrs - Coldthorn Moss area. Two features can be seen, one marking the top of the Fifth Grit, another occurring within the Coal Measures. Both are intermittent and not very bold. Exposure is very poor, 5 feet of flaggy, medium grained sandstone grading up into a grey siltstone with limonite lined vugs being all that is seen. These exposures occur in an old quarry (032252) which worked a member of the Cleveland Dyke. The beds dip east south east at 3° at the western end of the quarry, and west at 3 or 4° at the eastern end. The disparity is possibly due to the effects of the dyke.

South of the Northern Eggleston Fault, the downthrown Coal Measures are further disturbed by the north west - south east and north north west - south south east faults on Barnard Castle Allotment and Langleydale Common. No beds are exposed between these two faults, but on the north bank of Hindon Beck some small shale tips contain coal fragments, betraying the presence of a workable coal, probably the Brockwell Coal. East of the north north west - south south east fault the stream cuts down through the thick drift to reveal solid exposures. No one bed can be traced with certainty over any distance, the strata being highly variable laterally and the stream being a meandering strike stream in relatively steeply dipping strata.

Working downstream the first exposure is of 4 feet of medium grained buff sandstone (037247). 30 yards downstream 10 to 12 feet of fine to medium grained, flaggy and shaly buff sandstone crop out in the right bank, displaying minor washout phenomena.

An old coal drift runs due south into the right bank at this point, the first of a series of such drifts indicating the position of a workable coal probably that occurring upstream and which has been downfaulted to the east by the north north west - south south east fault. One hundred and thirty 130 yards due east of the latter exposure 40 feet of interbedded flaggy and shaly sandstone and sandy buff and grey shales crop out in the stream banks, dipping north north west at 20°. An old drift runs northwards into the north bank. A further 130 to 200 yards downstream the following succession is revealed:

		Ft.		Ins.
Sandy shale and shaly sandstone.		6	-	0
Gap (probably containing the coal worked in the drifts).		5	-	0
Limonite stained, buff, fine grained micaceous sandstone, shaly in places.		10	-	0
Gap.	5 ft. to	8	-	0
Fine grained grey shale	up to	15	-	0
Ganistroid buff sandstone.		3	-	0

At distances of 100, 160, and 260 yards downstream some useful exposures occur, confirming the relatively steep dip of the strata seen in an exposure upstream, and in the Millstone Grit to the south. The first exposure is of 6 feet of ganistroid sandstone dipping north at 18°; the second shows 1 feet 6 inches of fine grained flaggy, micaceous sandstone over 10 to 15 feet of sandy shales and thin sandstones dipping north west at 20°. Finally the third exposure shows some fine grained micaceous buff sandstone dipping north east at 15°. The sandstone is jointed in two directions: north 70° east, and north 25° west.

There are no further solid exposures, but to the east, north of the road to Woolly Hill (044249) at least sixteen old coal drifts (now collapsed) run northwards into the hillside. They are driven at two levels a few feet apart. Undoubtedly the higher drifts marked the outcrop of the seam, while the lower drifts were driven forward to meet the northerly dipping seam. In the extensive tips associated with the old workings contorted shales with a profusion of non-marine lamellibranchs lie around in abundance. Unfortunately the contorted nature of the shales renders the mussels (casts of which are preserved) difficult to identify, but Carbonicola sp. and Anthraconaia sp. occur. The seam is probably the Brockwell Coal.

The seam is regarded as the same coal that occurs upstream. Bearing in mind the steep dip of the strata in this area, the drifts north of the road are at a higher stratigraphical level than those upstream which leaves two alternatives. Firstly the eastern coal seam is the upfaulted equivalent of that to the west; secondly the western drifts work a lower coal seam. In support of this is the fact that no mussel bearing shales have been found on the old tips associated with the drifts to the west.

In the absence of positive evidence however, the seams have been regarded as the same and a conjectural fault drawn in roughly along Thistle Bog Sike, downthrowing to the west.

An estimated total of 200 feet of strata occurs between the Fifth Grit and the Brockwell Seam.

CHAPTER 5.

CORRELATIONS AND CLASSIFICATION OF THE CARBONIFEROUS.

THE P ZONE.

The classification of the Lower Carboniferous beds exposed in this area according to Garwood's Coral - Brachiopod scheme (1910, 1912), has already been discussed, together with the relevant information from this area (pp. 60-64). It now remains to place the succession within Bisat's Goniatite scale (Bisat 1924, 1928, 1933, 1934, 1936, 1950) as precisely as possible with the available information.

D.H. Raynor (1953, pp. 285 - 287) lists eleven important palaeontological discoveries throwing light on the age relationships of the Yoredale Series, but only two of these are cited as being beyond reproach. They are *Goniatites sphaerico - striatus* Bisat, a Plc fossil collected by R.G.S. Hudson from shale below the Hardraw Limestone of Askrigg, Wensleydale (Dunham and Stubblefield 1945, p. 257); and *Cravenoceras cowlingense* Bisat, low E2, in the Mirk Fell Limestone of Swaledale (Dunham and Stubblefield 1945, after Hudson 1941, p. 261). In addition, the recovery of *Girtyoceras ? costatum* Ruprecht and other goniatites referable to *Girtyoceras*, indicating a high P2 age, from a boring at Mount Pleasant, near Barnard Castle, from shale considered to lie between the Undersett Limestone and Undersett Chert (G.A.L. Johnson 1951), is thought by Raynor to be sound. She then tentatively suggests the following classification (p. 288).

The P1 zone includes the Hardraw Shale, some indeterminate distance below it and perhaps a little above it.

The P2 zone includes the Scar Limestone and beds up to the top of the Undersett Limestone.

The E1 zone includes the Main (or Great) Limestone, and may range upwards to take in the Little Limestone.

Above that the E2 zone continues high up into the Upper Limestone Series.

Trotter (1952) placed the base of the Namurian just above or below the Middle Limestone (p. 94), depending upon whether Hudson's *Cravenoceras leion* - *Eumorphoceras tornquisti* band is above or below the Middle Limestone at Black Hill - (Hudson and Cotton 1943, p. 170). There is doubt as to the true identity of the limestones concerned however (Raynor 1953, p. 288). Trotter correlated the Scar Limestone with the Acre Limestone and the Middle Skateraw and Burnhill Limestones of Scotland, on the basis of a zaphrentid fauna containing *Cyathaxonia cornu.* The latter limestone is overlain by the Neilson Shell Bed which contains high P2 species of *Sudeticeras.* Doubts concerning the advisability of employing *C. cornu* thus are raised by the fact that D. Hill (1938, p. 6) gives it a very long range in Britain, appearing as low down as the Z zone (see p. 61).

The occurrence of *Tylonautilus nodiferus Armstrong early mut.* Stubblefield in shales above the Four Fathom Limestone within the present area (see p. 62) and elsewhere, lends weight to Rayner's conclusion that the base of the Namurian lies somewhere between the Four Fathom and Great Limestones. It appears very likely, therefore, that the bulk of the Middle Limestone Group lies within the P zone, as suggested by Dunham (1948, p. 12). The Geological Survey have now in fact adopted the Great Limestone (Main Limestone) as the basal member of the Namurian.

Rayner's record of *Goniatites cf. granosus* Portlock from shales overlying the Scar Limestone at Bow Lees Quarry, north of

Middleton-in-Teesdale, (1953, p. 286) is the lowest record of a P2a fossil in Northern England. This specimen was identified by Bisat, and while Rayn~~o~~er admits it is poorly preserved, and that specimens have been found at higher horizons (Moore 1950, p. 44), it strongly suggests that the Scar Limestone lies near the P1 - P2 boundary, probably just below it.

With regard to the Middle Limestone Group, as exposed in the present area, it is probable that the beds up to and including the Scar Limestone lie within the P1 zone, while those up to the base of the Great Limestone are of P2 age.

The position regarding the top of the P1 zone and succeeding zones is less clear however.

THE E ZONE.

Correlations to the South.

The base of the E zone has already been discussed. R.G.S. Hudson (1941, p. 269) records Cravenoceras cowlingense Bisat in the Mirk Fell Limestone of Swaledale, which he (1945, pp. 2-3) and Trotter (1952, p. 96) regarded as marking the top of the E1 zone. Dunham and Stubblefield (1945, p. 136), and Dunham (1948, p. 12) place it at the base of the E2 zone, and are supported in this by Raynor (1953, p. 290). Hudson correlated the Mirk Fell Limestone of Swaledale with the Rookhope Shell Beds, and possibly the Lower Felltop Limestone, of the Alston Block (1941, p. 266), disagreeing with Carruthers correlation of the limestone with the Knucton Shell Beds (1938, p. 252). Reading (1954, pp. 103-06), however, maintains that the Mirk Fell Limestone (or Ironstone Series) and the underlying Mirk Fell Ganister, are unrepresented in north and east Stainmore. He correlated the underlying Upper and Lower Stonesdale Limestones with the Lower Felltop Limestone and Rookhope Shell Beds of the Alston Block, respectively. The correlation of the Transgression Beds Grit, at least in part, with the Kettlepot Ganister of Rogan's Seat, and the possible equivalence of the Coalcleugh and Tanhill Coals, have already been fully discussed (pp. 94 - 95). On this basis, the Mirk Fell Ganister - Grassington Grit horizon (shown to be equivalent by Rowell, 1953, p. 144, and Scanlon, 1955, pp. 161-2) is unrepresented in the present area and the Alston Block in general. Rowell (p. 76) also suggests that the Mirk Fell Ironstone Series is undeveloped under Mallerstang and definitely absent in the Ure valley (p. 77) although the Mirk Fell Ganister is present over the whole of the area. This offers some support to Reading's statements.

If one accepts the latters[1] correlations, therefore, the E1-E2 boundary would occur between the Lower Felltop Limestone and the Transgression Beds Grit of the present area.

Hudson's correlation would, of course, mean the equivalence of the Mirk Fell Ganister and the Grit Sills. If this is so, then the Grit Sills washout noted by Dunham extending from Hunstanworth to Stanhope (see pp. 166-167), could well form one of the sources of the thick grit developments of the Grassington Grit, which attenuates to the north west, being represented by a verb active 4 feet thick Mirk Fell Ganister in Mirkfell Gill (Rowell 1953, p. 64). Dunham (1950, p. 56) suggested that this Grit Sills washout represented, in E2 zone times, one of the sources of the thick grits of the Mid Pennines. This could only be so if the E1 - E2 boundary were placed below the Grit Sills, i.e. by accepting Carruthers correlation, which seems unlikely. Hudson's correlation would not necessarily invalidate Readings[1] contention that the Grit Sills die out southwards in the Stainmore area, while the Mirk Fell Ganister dies out to the north. The former could represent the thinning of the grit development to the south or south west of a distributary, while the latter represents the thinning of the grit development to the north or north west of a larger distributary lying to the east. The E1 - E2 boundary on the Alston Block would therefore lie below the Rookhope Shell Beds. The transgressive nature of the Grit Sills along these washouts (the Rogerly Transgression) could then be linked up with the sub Grassington Grit unconformity, the unconformity increasing to the south, where uplift was more pronounced, as evidenced at Greenhow (Dunham and Stubblefield 1945), and between Nidderdale and Wharfedale (Chubb and Hudson 1925).

Reading's correlation of the Upper Stonesdale and Lower Felltop Limestones is based on a constant and distinctive lithology (see pp. 92, 168). He points out that the horizon regarded as the Lower Felltop Limestone may represent the upper Rookhope Shell Beds. The limestone mapped as the Lower Felltop in the Tees and Lunedale (see pp. 158-159) does have a very distinctive lithology, and if this is true of the Upper Stonesdale then Reading's correlation is probably correct. The question as to whether this limestone in the Tees and Lunedale is the Lower Felltop or part of the Rookhope Shell Beds cannot be answered from evidence to the north, because of the variability of the Rookhope Shell Beds, and the probable absence of the Lower Felltop Limestone. The fact that beds assigned to the Rookhope Shell Beds are separated by 40 feet of strata, from the overlying limestones, suggests that the latter (themselves accounting for over 17 feet) represent the Lower Felltop Limestone.

Whether we accept the correlation of Reading or Hudson, the base of the E2 zone must lie somewhere below the Transgression Beds Grit in the present area. The difficulty lies in whether it occurs below the Rookhope Shell Beds, or above the Lower Felltop Limestone.

Reading (1954, pp. 118, 119) has traced the Upper Felltop Limestone of the Alston Block southwards into the Hearne Beck Limestone of the Askrigg Block. Above this the Fossil Sandstone of Stainmore can be correlated with the Fossil Grit of Swaledale and the marine shales above the Upper Felltop Limestone in the present area (see p. 98). The Botany Grit and Botany Limestone of Stainmore he correlated with the Water Crag Grit and Shunner Fell Limestone of Swaledale. This means that the marine band above the First Grit in the present area is equivalent to the Botany Limestone and the Shunner Fell Limestone. The latter has been correlated by Scanlon (1955, p. 200, fig. 4, p. 198) with the Colsterdale Marine Band (of proven high E2 age) on the basis of the fact that it contains Anthracoceras glabrum s.l. and Tylonautilus nodiferus ss. Armstrong, both considered diagnostic of E2. Unless the range of these two forms is extended, this latter correlation is the only feasible one. Chubb and Hudson (1925, p.335) correlated the Hearne Beck Limestone with the Colsterdale Marine Band, and the Shunner Fell Limestone with the Cayton Gill Beds on stratigraphical grounds. This meant that the Shunner Fell Limestone was of Low R1 age, and the Hearne Beck Limestone of high E2 age. The available palaeontological evidence favours Scanlon's correlation, and this has been adopted herein.

The age of the beds succeeding the marine siltstone in the present area is conjectural. We are left with the H., R., and G, zones, and possibly the Lenisulcata subzone to account for below the beds classed as the Low Coal Measures. The 350 feet or so of strata above the marine band may either represent a condensed sequence, or may conceal a fairly considerable non-sequence. There is no physical evidence of a strong unconformity within the beds, and palaeontological evidence is completely lacking. Trotter (1952. p.104) considered that the Northern Province was land in H, R, and G times.

Correlations to the North.

In the Brampton area Trotter and Hollingworth (1932) divided the Carboniferous strata into the Upper Bernician (D1, D2, and Dγ) and the Coal Measures with no Millstone Grit. They assumed that where the fauna was of Carboniferous Limestone facies they were indicative of Lower Carboniferous age. The grit above the Burnfoot Shales, the highest horizon yielding a Carboniferous Limestone facies fauna, was taken as the base of the Coal Measures (the primary surveyors took it as the base of the Millstone Grit). They correlated the Middle and Upper Oakwood Limestones with the Lower and Upper Felltop Limestones of the Alston Block.

Macgregor (1929) correlated the Scottish and north eastern Cumberland successions thus:

Castlecary Limestone	=	limestone below the Burnfoot Shales.
Calmy Limestone	=	Thornborough Limestone.
Orchard Limestone	=	Corbridge Limestone.
Index Limestone	=	Middle Oakwood Limestone

Just above the Index Limestone *Anthracoceras sp.* occurs, Currie
while *A. paucilobum early var.* and *Eumorphoceras bisulcatum near variata* are recorded from the Calmy Limestone, and *A.paucilobum* in the Castlecary Limestone (Macgregor and Pringle 1934) (Hudson 1941). *Tylonautilus nodiferus ss.* Armstrong has been found at horizons varying from the Corbridge Limestone to the Burnfoot Shales and their equivalents the Styford Shales (above the Harlow Hill Limestone) (Trotter 1952,p.103) (Jackson 1946,p.162) and in the Calmy and Castlecary Limestones (Macgregor 1929). All this evidence combines to place the beds from the Corbridge Limestone to the Burnfoot Shales, inclusive in the E2 zone.

Trotter placed the E1 - E2 boundary above the Middle

Oakwood Limestone (1952,p.87) on the basis of correlation of the latter with the Mirk Fell Limestone (or Mirk Fell Ironstone Series), through the Lower Felltop Limestone of the Alston Block (after Hudson 1941). This argument may be invalid, both because of the dispute concerning the position of Cravenoceras cowlingense, and the alternative correlation of the Mirk Fell - Stainmore - Alston Block succession (Reading).

There appears to be no direct evidence to place the Middle Oakwood Limestone in E2. The lack of such evidence tempts one to place it at the top of E1, in which case Reading's correlation (which places the Lower Felltop Limestone in E1) would be correct. This is purely negative evidence however, and should be treated with caution. If the Middle Oakwood - Lower Felltop horizon is equivalent to the Mirk Fell Limestone, then the writer would follow the practice of Dunham and Stubblefield (1945,p.136) and Raynor (1953,p.290) and place it within the E2 zone. e/

Much then depends upon Reading's correlations, upon their validity depends the position of the E1 - E2 boundary on the Alston Block, and its extension into Scotland. The top of the E2 zone is less difficult. The Colsterdale Marine Band is characterized by Cravenoceras nitidum in association with A. paucilobum, and placed at the top of E2. The top of E2 can therefore be placed above the Castlecary Limestone, and on the strength of T. nodiferus ss. above the Burnfoot - Styford Shales horizon (Jackson 1946,p.162).

Waite and Hedley (1928) gave the name "Harlow Hill Limestone" to the Felltop Limestone of south Northumberland, in which Hedley recorded T. nodiferus ss. (1931,p.237). This horizon was corrected to the overlying Styford Shales by Jackson (1946).

Hudson (1933,p.469) placed the Shunner Fell, Botany, Thornborough and Harlow Hill Limestones at the top of E2, but also stated that the Botany and Fell Top Limestones (Harlow Hill Limestone) may belong in part to zone H (p.462).

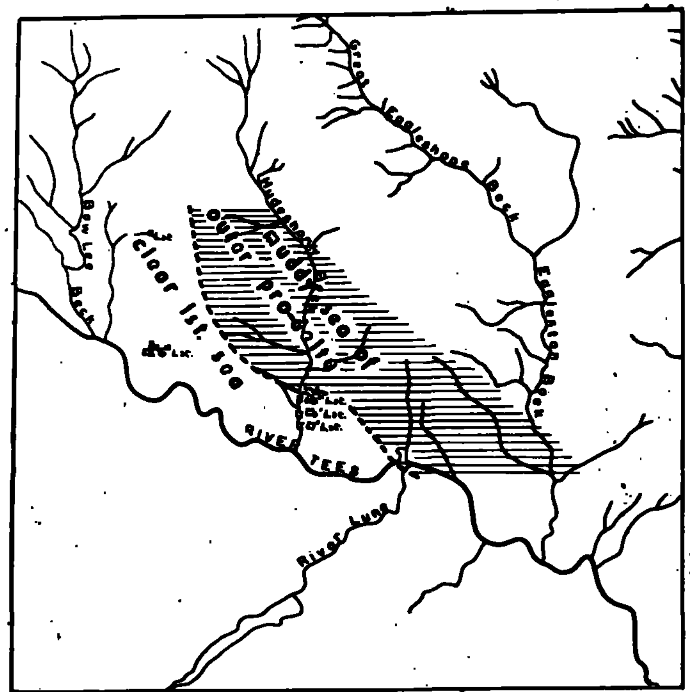


Fig. 8a Immediate Post 3 Yard Limestone.

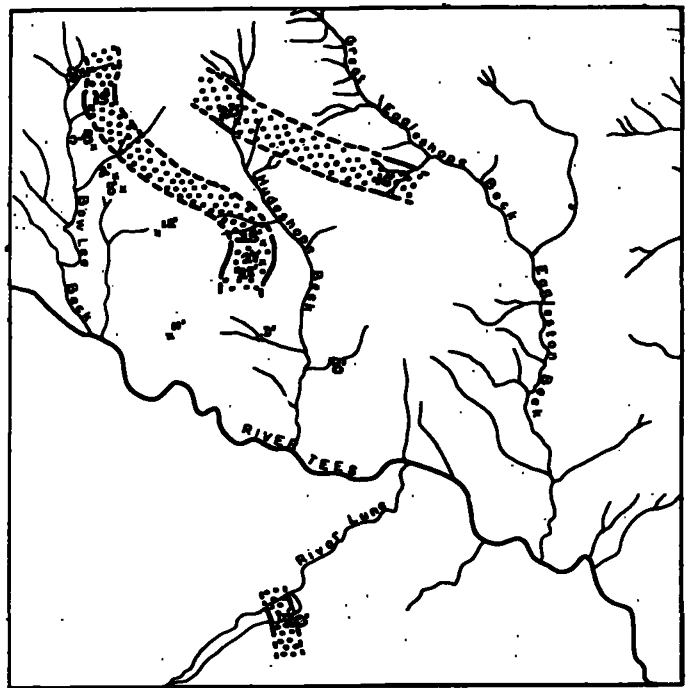


Fig. 8b. The Low Coal Sill.

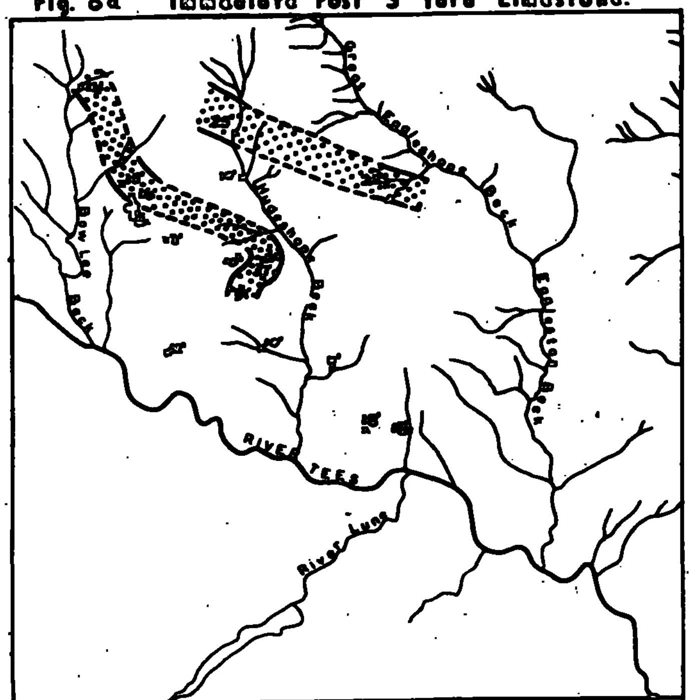


Fig. 8c. The High Coal Sill.

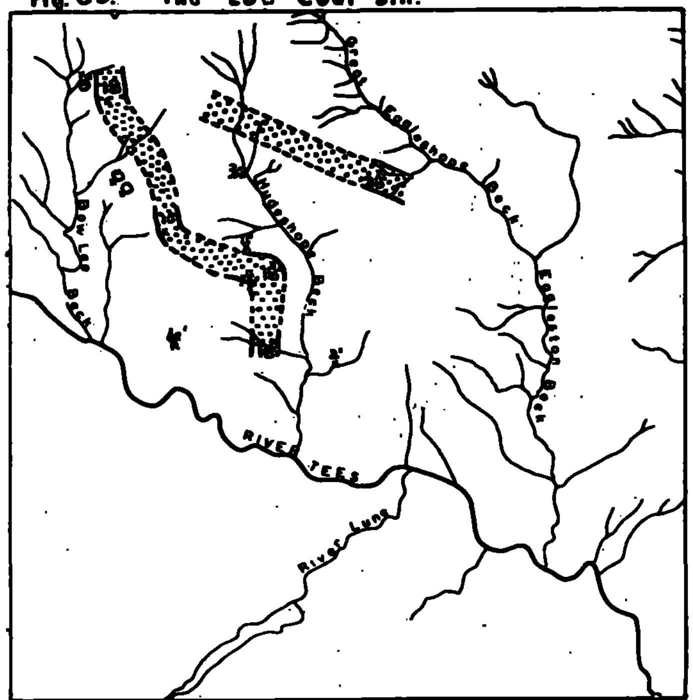


Fig. 8d. The White Hazle.

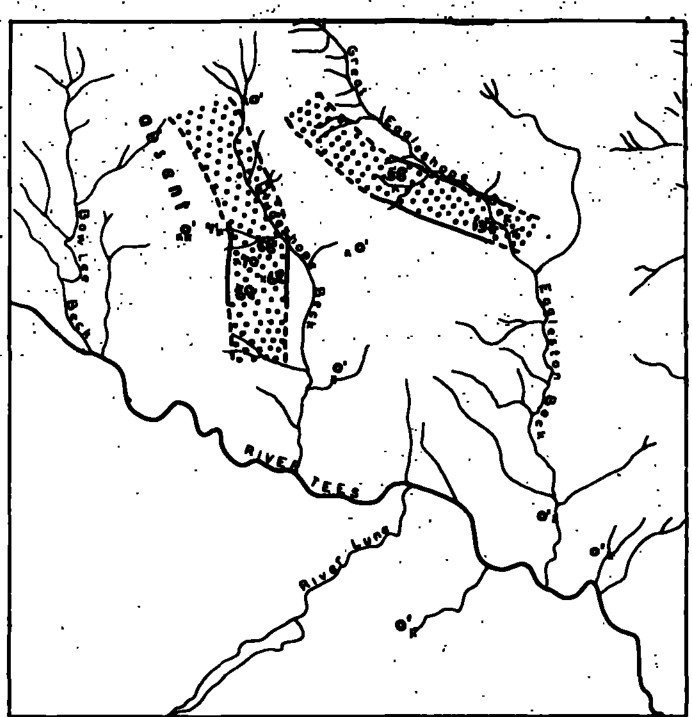


Fig. 8e The Firestone Sill.

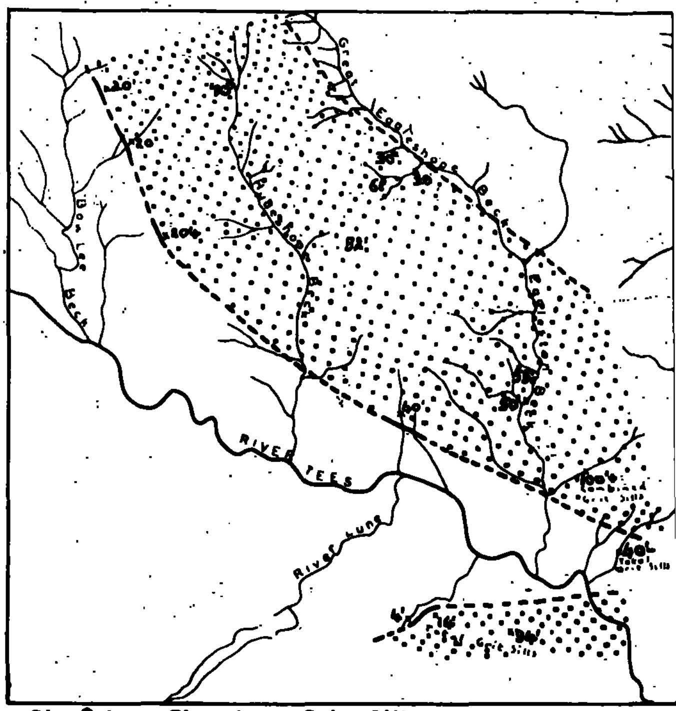


Fig. 8f. The Low Grit Sill.

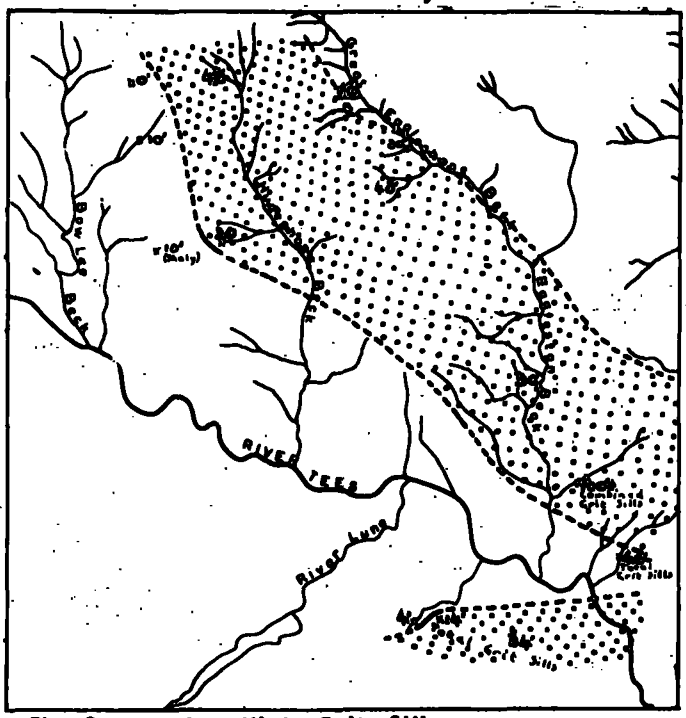


Fig. 8g. The High Grit Sill.

See p. 356.

CHAPTER 6.

THE CONDITIONS OF DEPOSITION OF THE CARBONIFEROUS SEDIMENTS.

GENERAL.

Upon examining the Carboniferous succession of the Alston Block one is immediately struck by two things; first of all by the rhythmic sedimentation, which is developed to a remarkable degree in the Middle Limestone Group; and secondly by the overall change in character as one ascends in the sequence, with the rhythmic sequence becoming less obvious, and with marine incursions becoming less frequent and of shorter duration. The change is gradual, with "Millstone Grit" type facies occurring well down in the Upper Limestone Group. Indeed, so well is this developed in the Transgression Beds Grit and Hipple Sill of the Tees below Eggleston (see pp. 181-189), that the primary surveyors mapped the coarse grits as 'Millstone Grit'. This gradual change in facies type must of course reflect a gradual environmental change.

The rhythmic character of such sediments was first brought to our notice by Hugh Miller (1887) who attributed the rhythmic deposition of the Upper Limestone Series of north west Northumberland to successive depressions of sedimentary basins, allowing marine invasions followed by silting up, emergence, and the growth of "coal forests." Subsequently various authors have given their attention to the phenomenon. R.G.S. Hudson (1924) studied the rhythmic succession of Wensleydale and recognised the following complete cycle; at the base 1) a limestone conglomerate resting on top of the limestone of the preceding rhythm; 2) calcareous shale with a "normal shale" fauna; 3) unfossiliferous ferruginous shale; 4) alternating shale and sandstone; 5) sandstone; 6) fireclay or ganister; 7) coal; 8) sandstone or coaly shale; 9) limestone (resting on an eroded surface). The lower part of the limestone contains a coral faunal phase, the middle part a coral-brachiopod or brachiopod faunal phase, and the upper part subsidiary shale with a "modified limestone" fauna, overlain by algal limestone or chert. The mechanics of this rhythm he regarded as a change in the nature of the material supplied, with a cessation of the supply of detrital material in the case of the limestone. Changes of level in the source area would account for this (p.135).

A study of the Middle Limestone Group as revealed at Beadnell, Northumberland led Brough (1928) to produce a standard rhythmic unit which differed from Hudson's mainly in the absence both of a limestone conglomerate, and of a sandstone or coaly shale above the coal. He points to the possibility of climatic changes as the cause of the rhythm. Wills (1929,p.318) considered the possibility of relating rhythmic sedimentation to the Milonkovitch climatic cycle, but thought it unlikely.

T. Robertson (1948) considered that gradual uneven shrinkage of different deposited materials, and the control excercised by vegetation and a lagoonal bar or levee, in an area of uninterrupted, even subsidence was sufficient to produce rhythmic deposition. Periodic breaching of the lagoonal bars or levees and the subsidence attending the compaction of sediments were responsible for the marine invasions. He excluded the Yoredale sequences from his considerations on the grounds that they were not truly rhythmical because of erosional breaks within the rhythms.

Dunham (1950,p.48) noted the minor importance of coals in the Carboniferous Limestone Series of Northern England, and hesitated to assign any important rôle to vegetational control of sedimentation, though admitting that it probably did exert some influence. He tabled as an ideal cyclothem for the Rigid Block (1950,p.50) : 1) marine limestone; 2) marine shale; 3) unfossiliferous (? non marine) ferruginous shale; 4) sandy shale, shaly sandstone, or "grey beds" (interbedded shales, siltstones and sandstones); 5) sandstone; 6) ganister or underclay; 7) coal. Hudson's limestone conglomerate was not included because of its restricted occurrence. The absence or restricted occurrence of some members, particularly of coal and marine shale, was also noted. The limestone was taken as the base of the cyclothem because the commencement of limestone deposition marked the most striking change of conditions. Dunham (1950,p.58) attributed the initiation of each cyclothem to general subsidence, "perhaps the result of delayed isostatic adjustment to the rapidly - accumulated sand delta".

H.R. Wanless and F.P. Shepherd (1936) suggested the control of sea-level by glaciations in the Southern Hemisphere to account for Late Palaeozaic rhythmic sedimentation. Weller (1930) invoked diastophism before sandstone deposition, and rapid submergence after the stage of coal forming swamps to account for rhythmic sedimentation very similar to the Yoredales in the Pennsylvanian of Illinois.

Gilligan (1919,p.276) considered the study of modern deltas essential to the understanding and correct interpretation of problems connected with the Millstone Grit and Coal Measures. This is no less true of the Carboniferous Limestone Series. It has already been pointed out that the change from typical Yoredale sedimentation to typical Millstone Grit sedimentation was a gradual process, implying a gradual environmental change. The work of Fisk, et al. (1954, pp. 76-99) on the Mississippi delta proves to be an admirable basis of comparison between present day deltaic sediments, and those of Carboniferous times.

The modern Mississippi birdfoot delta is merely the subaerial expression of a broad platform built out onto the floor of the Gulf of Mexico. This platform covers an area of 700 square miles, while the subaerial delta has an area of 131 square miles. The sediments transported in the various distributaries are deposited onshore within several environments of the delta plain, and offshore as stream mouth bars, and also within the extensive pro-delta zone of the delta front and Gulf floor (see pl. 22 encl.). The onshore environments include distributary channels with associated natural levees and marginal marshlands. Between the distributaries are shallow water basins, the interdistributary troughs, which are largely covered with lakes and bays. In places these troughs hold extensive marshlands, and near the seaward margins, sand spits and subaqueous bars.

Deposition is most active near the distributary mouths, creating bulges on the front of the delta platform resembling subaerial alluvial fans. The greater part of the sand and silt load of the river is deposited as distributary mouth bars on the upper part of the bulges. Fine silts and clays are carried distances of up to 65 miles seawards as plumes of turbid water, and deposited in the pro-delta environment. A large proportion of the sediments which flocculate from these plumes is deposited around the toes of the distributary mouth bars, forming the basal part of the bulge. Much of the remainder is deposited on the Gulf floor, but some is swept inshore by marine currents and reaches the interdistributary troughs. The sands deposited at the distributary channel mouths advance over the fine grained deposits of the pro-delta as "bar fingers" (see pl. 22 enclosed). Natural levees, built up to a height of 5 or 6 feet above water-level, and up to 1000 feet wide, are formed during flood periods. Sediments swept over the natural levees are carried into the shallow water basins of the interdistributary troughs. Waves and current action winnows the fine grained particles from the bay bottom sediments, leaving the coarser material to floor parts of the bay, or gathers some of the silts and sands to form spits and subaqueous bars.

The bar facies consists of sand grains from 0.5 to 0.05 mm. diameter, silts from 0.05 to 0.005 mm. diameter, and clays less than 0.005 mm. diameter. The bar sands accumulate to a thickness of 250 to 300 feet, and are massive and locally cross bedded at the top. They form the skeletal elements of the delta and are from 4 to 5 miles wide. Natural levees attain a thickness of 20 feet, and grade laterally into marsh deposits and down into bar sands. They consist of well bedded silts and clays. The clay wedges of the interdistributary troughs and delta front contain minor lenticular bodies of sand and silt, marking the position of spits and bars, in the upper part of the wedges. The lower sections consist of silty clays in which the percentage of clay increases with depth in much the same way as it does on the Gulf floor at increasing distances from the delta front. The basal unit of the deltaic mass is this upper part of a pro-delta marine clay layer approximately 300 feet thick throughout the delta area. The sediments of the pro-delta facies are sparingly fossiliferous where they grade into "bar sands", but become abundantly fossiliferous in the outer zones.

The amount of subsidence of the delta has been determined by Russell (1936) as 0.9 feet per year. Causes of subsidence include compaction of sediments and structural downwarping. The most pronounced affects of compaction are seen in the bar fingers and natural levees which change shape and elevation both while deposition is taking place and after burial. The bar sands thin seawards, due largely to compaction of the underlying silty clay unit during bar sedimentation (see plate 22). Compaction of the sediments below bar fingers after bar growth is completed is shown by the fact that the bases of the natural levees have sunk an average of 20 feet below sea level. In the interdistributary troughs, organic rich marsh sediments which were laid down above sea level, have been cored to a depth of 28 feet proving compaction of the underlying clays.

The birdfoot delta has accumulated under relatively uniform conditions (see Fisk, et al, pp.97-98) over the past 450 years. It would be interesting to surmise the effects of changing conditions, particularly if those changes were of a rhythmic nature. Such changes could be in the rate of subsidence of the Gulf floor; rejuvenation is the source area; climatic cycles possibly; or the outpacing of subsidence by sedimentation resulting in the silting up of the area culminating in emergence, swamp formation, and the prevention of free passage of sediments to the sea. Any of these, singly or in combination, would result in periods of clear seas in which, if conditions were suitable limestones would be deposited. Such deposition would cease with a renewed influx of river-borne sediment. Thus we have the essentials of rhythmic sedimentation. Initially, limestone would be laid down in clear seas; gradually fine muds and silts enter the area and these in turn would give way to coarser sediments, all forming the pro-delta facies of an advancing delta. The equivalent of the subaerial birdfoot delta would not reach the area for some time. In the meantime the rate of sedimentation may slow down or cease, from one or more of various causes, and marine conditions return. The succession, after lithification, would be limestone, shale, siltstone and/or sandstone, limestone. Eventually the delta proper, with its sedimentary framework of bar fingers and interdistributary trough clay wedges might reach the area. Consolidation of the sediments would result in a variable succession of shale (the pro-delta facies) grading up into sandstones (the bar fingers) on the one hand, and silty shale and siltstones, with lenticular sandstones (the clay wedges, with spits and bars) on the other. Marsh deposits might form coals or carbonaceous shale over seat earths.

It now remains to compare the results of Carboniferous sedimentation in the North of England with those proven and surmised in the modern Mississippi delta.

Previous authors, including Hudson (1924), Brough (1928) and Dunham (1950) in discussing the rhythmic sedimentation of the Carboniferous succession of Northern England, speak of a series of marine invasions. But, after the initial broad marine incursion, the situation is surely one of a series of deltaic invasions of a marine environment, with temporary halts which became less frequent and of shorter duration as the Carboniferous era progressed.

In general, widespread Carboniferous sedimentation was initiated on the northern, western, and southern flanks of the

Rigid Block in C1 times (? Z times in the Bowland Trough to the south), but the Block as a whole remained unsubmerged until S2 times (but see p.9), when a largely limestone succession was laid down. These conditions continued into D1 times (with only minor breaks), when the Melmerby Scar Limestone was deposited on the Alston Block, and part of the Great Scar Limestone on the Askrigg Block.

In the Northumbrian Trough to the north, deltaic sedimentation culminated in S times in the formation of the Scremerston Coal Series. Rhythmic sedimentation continued into D times, the Melmerby Scar Limestone being split up in the Brampton area with the incoming of shales and sandstones to the north (Trotter and Hollingworth (1932,p.47).

Rhythmic sedimentation advanced southwards across the Rigid Block, commencing in the north of the Block after the deposition of the Melmerby Scar Limestone (lower D1 times) and reached Wensleydale in Lower Little Limestone times (lower D2). This southerly migration of rhythmic sedimentation must surely reflect the general southerly advance of deltaic conditions, with the shales and fine grained sandstones representing the extensive pro-delta facies. A major 'retreat' of deltaic conditions occurred, for the Single Post Limestone and Cockle Shell Limestone cyclothems are represented by limestone only in the Askrigg Block (i.e. part of the Middle Limestone). Dunham (1950,p.54) notes this southerly "dying out of shale and sandstone members of the cyclothems from the Scar Limestone downwards, confirming, for this part of the succession, Wheelton Hind's contention that the Yoredales pass southwards into massive limestone (1902)." After Scar Limestone times, rhythmic sedimentation prevailed over the Rigid Block as well as in Northumberland and Scotland.

On the Alston Block the Upper Limestone Group witnessed the general influx of coarser material, although the Tuft develops a coarse grit facies in places (Dunham 1948, p.24). The delta proper was advancing with coarse grit facies occurring in ribbon developments at various horizons, e.g. in the Coal Sills at Hunstanworth, Boltsburn, Blackdene, and Coldberry (Dunham 1948, pp.28-29); and in the Grit Sills in a north- south belt extending from Blanchland and Hunstanworth through Stanhope and nearly reaching Middleton-in-Teesdale (Dunham 1948, p.37). These washouts in all probability represent distributary channel bar fingers. The fact that they are transgressive in places is a result of having to scour a channel through pre-existing deposits due probably to relative uplift at that point. Referring to the Grit Sills washout, Dunham (1948, p.56) suggests that it marks the site of a great river which possibly formed one of the sources, in E2 zone times, of the thick grits of the Mid Pennines (see p. 329).

To the south, on the Askrigg Block, correlation problems lend a certain difficulty to direct comparison of depositional conditions with those on the Alston Block (see pp. 335 - 341).

"Millstone Grit" times, on the Alston Block, was the scene of the deposition of sheets of coarse grit, shales, and some coals, with very few and limited (both in extent and duration) marine invasions. These sedimentation conditions culminated in the Coal Measure swamps, when deposition generally outpaced subsidence of the delta area. Distributary channel bar fingers are apparently lacking, or poorly developed (see pp. 245 - 324).

There are two important differences between the sediments of the Mississippi delta and the Carboniferous delta of Northern England. There is of course the absence of limestones in the marine facies of the former, but this need raise no insurmountable objections to the comparison. Then there is the question of the coarseness of the arenaceous Carboniferous sediments as compared with those of the birdfoot delta. This also offers no insurmountable objections. The Carboniferous land areas were vegetational deserts, in particular there was the absence of the all important grasses, which play such a vital part in the control of present day subaerial erosion. The affects of rain storms in modern arid regions need no comment here. The results of a wet climate, such as probably existed in the mountaineous source area envisaged to the north in Carboniferous times by many authors (including Sorby, 1859, p.675; Gilligan 1919, pp280-83; Dunham 1950, p.58), can be well imagined, with the erosion and transportation of coarse unsorted material proceeding apace. The climate must have been wet to give rise to rivers large and powerful enough to build such an extensive delta (at least 2000 square miles). To carry such coarse grained material over any great distances the rivers must have been fast flowing and turbulent. Dunham (1950, p.58) has pointed out that the abundance of carbonaceous material is not consistent with arid conditions. This need not invalidate the postulation of desert land areas, the material could be picked up in the thickly forested coal swamps.

DETAILED INFORMATION.

That part of the Middle Limestone Group exposed in the present area displays the characteristic rhythmic sedimentation associated with the group over the Alston and Askrigg Blocks.

The limestones, of course, represent periods of relatively clear marine conditions. They were followed by the gradual influx of detrital material, resulting in the deposition of fossiliferous, frequently calcareous shales immediately above the limestones, as the marine fauna struggled to exist. Continued influx of muds rendered conditions unfavourable for marine faunas, and largely barren shales with ironstone nodules were deposited in a slightly reducing environment. The marine shales represent the outer zone of the pro-delta, which gradually retreated seawards before the advancing delta, to be replaced by the succeeding almost barren shales. These in turn gave way to the coarser grained sandy materials. These formed the inner zone of the pro-delta and were probably accumulated beyond the seaward margins of bar finger sands, and in the interdistributary troughs through the action of currents and the breaching of levees during flood periods. Coals, such as are developed in Bow Lee Beck and Hudeshope Beck below the Three Yard Limestone (see pp. 35-6, 42-3), represent periods of emergence and coal swamp formation.

In Lunedale the Alternating Beds were seen to consist of shales and thin limestones, with a poor development of sandstone (see p. 23-24), while to the west, on Crossthwaite Common, and in the Tees, sandstone assumed a more important role. It has also been noted that the Cockle Shell Limestone became muddier and attains a locally abnormal thickness of 9 feet in Rowton Beck (p. 28). This suggests that Lunedale lay near the seaward limit of the pro-delta in Alternating Bed times, and it will be recalled that the Single Post and Cockle Shell cyclothems were represented by limestone only on the Askrigg Block (p. 352).

In Laddiegill Sike, Brokergill Sike, and Hudeshope Beck the Three Yard Limestone is succeeded, after some thin shales, by a limestone which attains a thickness of 12 feet or more. In Hudes Hope, however, it can be seen to thin upstream, giving way to fossiliferous, calcareous shale (see pp. 20, 43-44). This represents the seaward limit of the pro-delta facies at that particular time in this area.

The Nattrass Gill Hazle, Quarry Hazle, and Tuft, all thicken in a northerly or north westerly direction in the Hudes Hope - Coldberry area. Also, these beds thin to east and west (see pp. 54 - 56). This strongly suggests that the Coldberry area (in particular Skears Great Rise) was the site of a bar finger in those times, situated near its southern limit, with finer grained silts and muds being carried southwards to form the shaly succession of the pro-delta area. It is interesting to note that the Quarry Hazle attenuates from the base upwards in Hudes Hope (see p. 54), recording the gradual southerly advance of the coarser material.

After the deposition of the Great Limestone, deltaic conditions advanced with renewed vigour, giving rise to the ribbon sandstone/grit developments already described in the Coal Sills, the Pattinson/Firestone Sills, and the Grit Sills (pp. 79-83, 85-88), which no doubt represent bar finger sands. The significant fact about these thick sandstone developments is that they occur in approximately the same places at successive horizons, indicating that the distributary channels maintained roughly constant courses from Coal Sills to Grit Sills times (see figs.8b-g, p. 345).

In the sandstones and grits of higher horizons, including the local Millstone Grit, it has not been possible to trace any definite ribbon sandstone developments. However there is a general increase in the thickness of sediments to the east. This is evidenced by the easterly thickening and splitting of the Transgression Beds Grit (pp. 92 - 94.); the incoming of a sandstone/grit correlated with the Hipple Sill (pp. 93 - 94); the general thickening of the Grindstone Sill to the east, and the greatly thickened succession of shales and sandstones between it and the First Grit in the Eggleston-Pallet Crag area (pp. 98 - 100); the easterly thickening of the First Grit, and the incoming of the Second Grit. All point to the existence of an important distributary, unloading material in this area from a northerly direction. It's course cannot be traced with the available information and there is the possibility that the material represented by the various horizons was redistributed by offshore currents to form sheet grit and sandstone deposits. This is supported by the widespread occurrence of a calcite cement in the Transgression Beds Grit, the Hipple Sill, and Grindstone Sill, which may indicate deposition under marine conditions, and by the presence of an irregularly developed marine limestone capping to the latter (see Chapter 3). 8

Although no ribbon developments can be demonstrated in the First Grit, it was noted that the grit was actively transgressive in what appeared to be a north-south belt along the Hudes Hope Great Eggles Hope watershed (pp. 247 -249). This might represent the site of a minor distributary, but is conjectural.

Information from neighbouring areas to the south is of interest. Wells (1955,p. 178) and Scanlon (1955,pp.46-9) have shown that the Coal Sills delta dies out to the south in

Swaledale, with the grits, sandstones, and shales of the north giving way to shales, cherts, cherty limestone, and crinoidal limestones. Wells attributed the formation of the Main and Little (or Richmond) Chert Series to the deposition of silica from a great river which he tentatively identified with the Coal Sills washouts in Teesdale and Weardale noted by Dunham (1948,pp. 28-29).

The Grit Sills are represented in Lunedale by a single coarse grit which thins rapidly to the west. Reading has drawn our attention to the diminishing importance of the Grit Sills in Stainmore when traced southwards, and points out that no mention is made of grit below the Lower Stonesdale Limestone (correlated with the Rookhope Shell Beds of the Alston Block) in the Mallerstang Memoir (1954,p.72). It thus appears that the coarse facies of the Grit Sills delta did not reach beyond Stainmore, giving way southwards to the shales and thin sandstones of the pro-delta facies.

Reading (1954,p.79,fig. 9) mapped a roughly north-south band of thick grit in the western part of Stainmore, running through Iron Band. He mapped it as the equivalent of the Middle Grit of the three Transgression Beds Grits of eastern Stainmore; separated from it by a central "mixed facies" of shales and thin sandstones. The Coalcleugh Marine Beds are restricted to the centre of the mixed facies deposits, with no equivalent in the areas of grit lithology. It appears likely that this mixed facies represents interdistributary trough deposits with a thin marine facies, flanked on either side by coarse bar finger deposits.

At a lower horizon, Reading correlated his Pebbly Grit (the

Transgression Beds Grit of the present area) with the Kettlepot Ganister of Swaledale. An equivalent grit horizon is apparently undeveloped or poorly developed in south and west Stainmore. Rowell (1953,p.92), with reference to the Lower Lindrigg Grit - Kettlepot Ganister horizon, states that the distribution of coarse material and thickness variations suggest one, possibly two distributary channels running east - west across the Tan Hill-Swarth Fell area. Scanlon (1955,p.164) traced the northernmost of these into the Shunner Fell - Rogans Seat area to the east, where it splits up into three subsidiary channels. It would seem that these various channels are minor distributaries branching from a larger channel to the west. This channel possibly followed a roughly north-south course passing west of Stainmore in rough parallelism with that in the Tanhill Grit - Middle Grit at a higher horizon. The tendancy of such channels to follow relatively constant courses has been noted within the present area.

The striking similarities between Carboniferous sedimentation phenomena and those of the present day Mississippi delta leave little doubt as to the mode of formation of the former. The major difference is the rhythmic character of the Carboniferous deposits for which various mechanisms may be responsible. Inability to trace accurately and completely the courses of the various distributary channels is of course due simply to inadequate exposure and not to lack of development of such phenomena. After all, in sediments of an admittedly deltaic origin it is to be expected that sedimentary structures and facies variations met with in comparable modern deltas, will occur.

THE MECHANISM OF RHYTHMIC SEDIMENTATION.

The process of delta formation has already been outlined, with the encroachment of clear marine conditions by muddy then silt or sand carrying water forming the pro-delta facies, and finally perhaps the building of a counterpart to the birdfoot delta with its bar fingers and clay wedges. If we imagine this process continuing until base level is reached in the source area, the river load would of necessity become finer grained. These sediments would be carried across the birdfoot delta to the pro-delta areas, and as the supply became diminished and finer grained, the silt and sand of the inner zone of the pro-delta would be succeeded by mud, to give a shale, sandstone, shale succession. Meanwhile there would be little or no deposition on the subaerial birdfoot delta, probably supporting a coal forest (which may or may not be preserved as coal). Sedimentation, which had either kept pace with, or outpaced subsidence of the depositional area (shales, sandstones and limestones alike show signs of shallow water deposition), would therefore gradually come to a halt. Subsidence would continue, perhaps slightly faster under the load of sediment (but not necessarily), and allow the return of clear marine conditions over an almost plane surface in an area receiving little or no sediment. Thus limestone would be deposited over the pro-delta and subaerial delta, over shale, sandstone and coal alike. Rejuvenation in the source area, suggested by Hudson (1924), would result in a fresh influx of material.

This does not, apparently, explain the typical Yoredale rhythm of limestone, shale, sandstone, coal, limestone. It is here submitted that such a standard rhythm is over-standardized. Dunham (1950,p.50) states that some members of the standard cyclothem, particularly the coal and the marine shale, are absent from some cyclothems. Limestones are the most reliable units and are persistent over the whole of the Rigid Block and often into Northern Northumberland.

A glance at the comparative sections of the Middle Limestone Group (fig.1,p.14) will show that the typical sandstone, development below the limestone of a standard cyclothem is frequently either absent, very poorly developed, or succeeded by shale or shale and sandstone alternations. Thus the Single Post Limestone overlies shale in Lunedale Quarries, 10 feet of sand-stone in Rowton Beck, and a 5 feet sandstone in the River Tees near Scoberry Bridge. The Scar Limestone succeeds a thin sandstone in the majority of exposures in the area, but in the east bank of the River Lune, near Lunedale Quarries it overlies the Cockle Shell Limestone directly. Dunham (1948,pp.19-20) states that shale generally separates the Low Brig or Slaty Hazle from the overlying Five Yard Limestone in the Northern Pennine Orefield. In this area, generally speaking, the Low Brig Hazle is succeeded by shale and sandstone below the Five Yard Limestone. In Sommerhill Force, Bow Lee Beck, 14 feet of alternating shale and sandstone intervene between the two horizons, 8 to 10 feet of similar beds in Hell Cleugh, and 9 feet in Newbiggin Beck. In the Tees, the Low Brig Hazle is capped by 15 feet of sandy black shales below the Five Yard Limestone.

The Five Yard cyclothem is similar. In the east bank of Bow Lee Beck near Mirk Holm (see p. 35), the High Brig Hazle is separated from the Three Yard Limestone by just over 20 feet of alternating shales and sandstone, including 4 inches of coaly shale. In the Hudeshope Beck exposures the Three Yard Limestone overlies up to 20 feet of shales with a few thinly developed sandstones, above the High Brig Hazle.

These sections then, would seem to represent the normal advance of a delta, culminating, in this particular area, in the deposition of sandstone in the inner zone of the pro-delta facies, followed by a gradual return to clear marine conditions as the rate of sedimentation slowed down. It is significant that the Low Brig Hazle gives way vertically to shale and sandstone (rather than shale) below the Five Yard Limestone, in Bow Lee Beck, where the hazle attains its thickest development, suggesting the closer proximity of bar finger sedimentation.

The Nattrass Gill Hazle, Quarry Hazle, and Tuft were seen to attenuate rapidly to the west, south, and east of Coldberry, the suggested site of successive bar fingers (see pp. 54-56,). The succeeding limestones, the Four Fathom, the Iron Post, and the Great respectively, rest upon sandstone, fireclay or shale, depending upon their location relative to the bar fingers.

Similar conditions exist in the Upper Limestone Group. The Crag Limestone overlies thick shale in western Coldberry Gutter, and coarse grit in the eastern part of the Gutter, near the western edge of a Firestone Sill bar finger (see fig. 8f p. 345). To the east in northern Hudeshope Beck, and in Lodgesike Mine, and the left bank of Hudes Hope to the south, the Firestone Sill is absent and the limestone rests on shales or thin ganisters. Likewise over the remainder of the area (where the underlying beds are exposed) in Snaisgill Sike, in Stobgreen Sike, and in Shields Beck, the Crag Limestone overlies shale, with the Firestone Sill undeveloped.

All these facts fit in very well with the conditions of sedimentation suggested above. The standard cyclothem of limestone, shale, sandstone, followed by limestone etc., required the sudden cessation of sedimentation when it was at its peak. Sudden subsidence in the area of deposition, or sudden uplift in the source area have been suggested. It is difficult to imagine such processes acting rapidly enough to prevent the influx of mud into an area after the deposition of sand.

The influence of swamp vegetation no doubt played a part in the control of sedimentation. In conjunction with the formation of spits and bars across the distributary mouths it might prevent the free passage of material to the open sea. The shale intercalations in the thicker limestones (the Scar, Five Yard, and Great Limestones) might be the result of periodic breaches of such bars. The effect of such controls would be felt suddenly. An objection to this hypothesis which might be raised is the failure to locate sedimentary bodies in the Carboniferous beds of Northern England, which might re-present those bars and spits. One might, however, suggest that they are represented by the ribbon grits of the so-called "washouts". N. Wood Bass (1939, pp. 559-581) has described the Verden Sandstone of Oklahoma, a shoe-string sandstone of Permian age. It extends for a distance of 75 miles, varies in width from 200 to 600 feet normally, but locally is up to 1,500 feet wide. Its thickness ranges from a few inches at the edges to 15 feet or more near the middle. It is current bedded, and deviates from a straight line only in broad sweeping curves. Bass considered it to be a spit or closely related chain of spits, extended across the mouth of a bay. It certainly bears a superficial resemblance to the ribbon grits of the beds under discussion. It differs in one vital respect however, its base and top are about horizontal, it does not occupy a channel of any sort and shows no transgressive tendencies whatsoever. In any case, the ribbon grits of the present area are flanked on either side by shales or shales and sandstones, there is no marine limestone facies to represent seaward deposits. The difficulty of demonstrating such structures in the Carboniferous deltaic sediments up to and including the Millstone Grit, remains therefore.

It is suggested that the great variation in facies within the Carboniferous Limestone Series and Millstone Grit are fully explained by the hypothesis of an advancing delta similar to the modern Mississippi delta. The rhythmic sedimentation is the result of periodic uplift in the source area, following by denudation to base level, the materials being deposited on a slowly, evenly subsiding shelf area.

THE SOURCE OF THE SEDIMENTS.

The first to consider the source of the materials forming the Millstone Grit was H.C. Sorby(1859), who concluded that the source area was a granitic mass (pp.673-74). Hull and Green (1864,pp.319-23) noted that there was a pronounced attenuation of the Millstone Grit to south and south east when traced from Lancashire and Yorkshire to the North Staffordshire Coalfield.

Gilligan (1919,pp. 278,279) also noted these facts and concluded from them that the source could only lie to the north, St. George's Land to the south being ruled out as inadequate and not having the necessary lithological character. The Lake District was shown by Garwood (1912, p.553) to represent an area of subsidence in Lower Carboniferous times. The Southern Uplands formed a land area in Lower Carboniferous times (Gilligan 1919, p.279), and according to Goodchild material from this area is to be found in beds of the Basement Carboniferous of the North of England. Gilligan considered the area inadequate to supply any large proportion of the Grit Series of Yorkshire, though it may have contributed to the homotaxial deposits further north. Lithological considerations also rule this area out; the large quartz pebbles of the coarse grits and some of the micaceous material of the shales resemble the rock-constituents of the Southern Uplands, but the pebbles of fresh felspar and pegmatite abundantly present in the Millstone Grit were not derived from that district. Also the granites forming the highest points in Galloway are rich in sphene, which has not so far been found in the Grit. Gilligan was therefore forced to the conclusion that the area lay further north, in what is now northern Scotland, extending eastwards into Scandinavia (p.281). This conclusion was reached by Sorby (1859, p.675), Hull (1882, p. 37) and (1885 p. 305), Green (1878, p.38), and Jukes-Browne (1892, p.131). Only Sorby adduced any evidence from the lithology.

That the source area lay to the north seems indisputable, both from the lithological and stratigraphical reasons given by Sorby and Gilligan in particular. Such a conclusion is essential to the hypothesis put forward in the present work regarding the building up of the Carboniferous delta.

The petrographic differences between the Carboniferous arenaceous deposits of this area (including the local "Millstone

Grit"), and the Millstone Grit of Yorkshire as recorded by Gilligan, have already been pointed out (pp. 325 - 331). Of particular importance is the almost complete absence of microcline;the general paucity of felspar (which is usually corroded when present); and the absence of garnet. Rowell (1953,pp.203 -204, 215) found the same differences in the "Millstone Grit" of the Tan Hill - Swarth Fell area and the Stainmore Outlier, to the south of the present area, except that some garnet occurs locally in calcareous sandstones. Optically strained quartz formed the bulk of the arenaceous beds in both areas.

In comparing these areas with those examined by Gilligan however, it should be remembered that he dealt with grits of R zone age, and that there are no proven deposits of this age in the present area and that mapped by Rowell. The differences may therefore be due merely to erosion of different rocks at different levels with the passage of time. The character of the component materials of the arenaceous beds of the present area strongly suggest that the source area was one of metamorphosed sediments - e.g. the optically strained quartz, some showing definite second cycle phenomena. The grade of metamorphism cannot have been very high judging from the poor suite of heavy minerals and the absence of garnet in particular. Comparing this with Gilligan's source area of acid granitoid gneiss with pegmatite veins, acid dykes, some unaltered granites and some sediments (p.275) we are left with one of two alternatives: that the source area was the same, with the R zone deposits representing erosion at a lower stratigraphical level of higher grade metamorphic~~s~~ rocks; or that the R zone grits were derived from an area of higher grade metamorphism lying to the east of that providing material for the present area. The source of material for this area might have lain in the Southern Uplands, but much petrographic work needs to be carried out before any categoric statement can be made in that direction.

If the source area was the same it implies that the present area was one of non deposition in R. times at least.

Also Kinsb E grits

There remains the question of the thick R zone grits south of the Craven Faults. It seems unlikely that any large preportion of the material forming these beds was carried across the delta discussed herein. Such would necessitate a prolonged period of emergence of the delta preventing deposition during R and possibly H. and G. times. It is very unlikely that such a period would not be accompanied by extensive erosion. There is no evidence of any such erosion in the higher levels of the Millstone Grit of the present area. Probably, therefore, the present area was one of non-deposition, with no extensive river system traversing it to supply the deltaic deposits of R age south of the Craven Faults. The latter deposits were probably supplied by a large river system flowing southwards somewhere to the east of the present area.

CHAPTER 7.

IGNEOUS INTRUSIONS.

A comprehensive study of the igneous geology of the area is beyond the scope of the present work, but the distribution and relationship of the various intrusions with the sedimentary country rocks must be dealt with. Such rocks fall within three groups: the quartz - dolerite Whin Sill; related dykes with a general east north east trend, the Whin Dykes; and a suite of tholeiitic dykes having a general east south east trend, known collectively as the Cleveland - Armathwaite Dyke. The age of the Whin Sill and Dyke intrusions is considered to be Hercynian (late Carboniferous - early Permian), that of the Cleveland Armathwaite Dyke, certainly post Jurassic, probably Tertiary (Dunham 1948, pp. 51, 59-60).

THE WHIN SILL

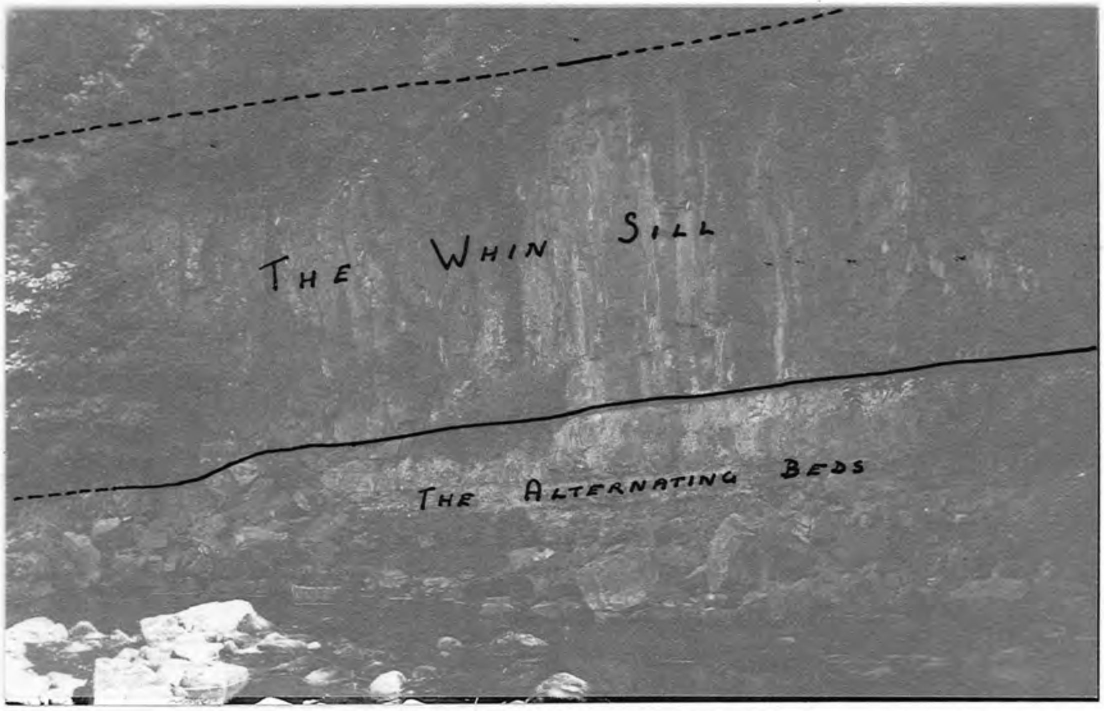
The Whin Sill was so-called by the Alston miners, who regarded it as a normal member of the succession (Dunham 1948, p.51). Phillips and the earliest geologists considered it to be a contemporaneous lava flow. The intrusive nature of the Whin Sill was first suggested by Sedgwick (1827) and proven by Tate (1870) and Topley and Lebour (1877). Later work demonstrated its variable horizon within the Carboniferous succession including that of Clough (1880), Weyman (1911, 1913), the Geological Survey (Gunn et al, 1927), Trotter and Hollingworth (1928), and Dunham (1948).

The petrography of the Whin Sill has been thoroughly investigated, notably by Teall (1884), Holmes and Harwood (1928), Smythe (1930), Tomkieff (1929), while its metamorphic effects, both on contiguous sediments, and within the sill, have been described by Hutchings (1895), Trotter and Hollingworth (1928), and Wager (1928, 1929). Dunham has summarized the petrography, giving four normal types of quartz dolerite (1948,p.56):- 1) Tachylitic marginal facies, a black very fine grained rock in which crystals are generally not visible without the use of a microscope; 2) Fine grained grey (or if weathered, greenish) dolerite, in which ferromagnesian minerals and felspars are plainly discernible using a hand lens; 3) Medium-grained mottled dolerite, in which the principal constituents are visible to the naked eye; 4) Dolerite pegmatite of two types, one grey, rich in large pyroxenes up to 2 cm. long, the other a pink granophyric variety. The estimated mineral composition of the intrusion, based on the chemical work of Smythe, and micrometric measurements by Holmes and Tomkieff, was given as: Pyroxene, 34%; plagioclase felspar 46%; hornblende, biotite, chlorite 4½%; iron-titanium oxides, 8%; quartz, orthoclase and micropegmatite, 5½%; calcite, pyrite, apatite 2%. In addition (p. 103), a fifth type of Whin, the "White Whin" occurs adjacent to mineral veins, where the dark quartz-dolerite has been altered to a white, lighter rock, which has been investigated by Finlayson (1910 pp. 304-5), Wager (1929), Smythe (1930,pp. 116-126) and Dunham (1948, pp. 103-107). The rock consists of secondary carbonates, kaolinite, micaceous clay minerals, anatase or leucoxene, and residual quartz and apatite.

In Teesdale the Whin Sill is exposed almost continuously from the head of the dale to the Lune confluence, on the southern side of the valley. Within the present area it presents a bold, craggy, fault scarp face where upthrown to the south by the Southern Teesdale Fault, with its upper surface forming a

Plate 16.

A. The Whin Sill, Middleton Quarries. The sill here is at least seventy feet thick and appears to thin to the south east(left).



B. The Whin Sill Lunedale. The full thickness of eighteen feet is revealed here overlying shales, thin sandstones and thin limestones.

east south east or south east attenuation. This is borne out by the fact that in Lunedale Quarries (954238), and in the banks of the River Lune, approximately half a mile south east of Middleton Quarries, a full thickness of only 18 feet is revealed. We are undoubtedly very near the southern limit of the Whin Sill in this area. To the north west, in Ettersgill Beck, beyond the western limit of the present area, borings have proved thicknesses of 221 feet 6 inches (E.T./16) and 243 feet (ET/11)(Dunham 1948, p. 52).

In Lunedale the much attenuated Whin Sill crops out in the bed of the stream 370 to 400 yards west of Lune Bridge, and rises upstream under the influence of a low angle dips varying from north east to due east. It is well exposed in the right bank and the old quarries in the left bank.

The only remaining exposures within the area mapped occur in Bowbank (945237) and to the south west. These outcrops lie north west of a north east - south west fault throwing about 100 to 125 feet to the south east. Exposure is not good, but the base of the sill (No.220c,d) overlying recrystallized fine grained sandstone, crops out at Bowbank in Hell Gill immediately south of the road. Its position with regard to the Scar Limestone, which outcrops in Moss Gill north of the road, is similar to that in Lunedale Quarries. To the south west, at the eastern end of Limestone Hill (942234), the top few feet of the sill are exposed, overlain by recrystallized sandstone, and baked shale. The full thickness of the sill is not seen at either exposure, but it cannot be much more than 15 to 20 feet as at Bowbank, the base of the Scar Limestone outcrops about 40 feet above the base of the sill.

The horizon of the Whin Sill is relatively constant, being intruded between the Tynebottom and Single Post Limestones throughout the area, as far as is known. Approximately 30 feet of beds occur between its upper surface and the base of the Single Post Limestone in the River Lune, and in Rowton Beck to the north west, inspite of the vast difference in thickness of the sill in the two localities. Recognisable beds below the Whin Sill are seen only in Lunedale, where at least 70 feet of beds occur between the base of the sill and the top of the Tynebottom Limestone, but 64 feet 6 inches of shales and sandstones are recorded between these two beds in one of the Ettersgill borings (ET/16) (Dunham 1948,p.56). There is a possibility that the sill has risen slightly in the succession at Bowbank, but as the base of the Scar Limestone, the Cockle Shell Limestone, the Single Post Limestone, and the top of the Whin ~~aren't~~ are not seen, this cannot be satisfactorily demonstrated. With the base of the Whin and the Scar Limestone about 40 feet apart however, it remains a possibility.

The metamorphic effect of the Whin Sill is not very marked in that part of Lunedale mapped. In Bowbank and east of Limestone Hill there has been a certain amount of recrystallization of sandstone, and baking of shale, but in the Lune River and Lunedale Quarries exposures the only effect is the baking of the shales in immediate contact shales.

To the north east, on Crossthwaite Common, and in the Tees near Scoberry Bridge, the Single Post Limestone has been completely recrystallized to produce a crumbling saccharoidal limestone (No. 275). Underlying shales and sandstones have also been metamorphosed. The limestone (No.31) exposed below the sill near Crossthwaite Quarry has also been recrystallized.

Plate 17.

A. The Whin Dyke, Eggleston Burn, intruded into the High Grit Sill. Its thickness is twenty eight feet in this section.

B. The Cleveland Dyke, Eggleston Burn, intruded into the Grit Sills and associated strata. The dyke is fifty seven feet wide in this locality.

THE WHIN DYKE.

The Whin dyke met with in this area belongs to the Hett Dyke System which includes the two small dykes seen on the escarpment near Long Fell Mine, the Connypot Dyke, seen in the headwaters of the Lune, the Greengates dykes previously quarried one and a half miles south west of Middleton-in-Teesdale, and the Hett Dyke proper which, according to Dunham (1948,p.59) runs from the Tees west of Middleton to the Permian escarpment near Quarrington Hill, 4 miles south east of Durham. This latter dyke was not located in the Tees west of Middleton in the present survey, its first recorded appearance being in Eggleston Burn approximately 1,100 yards north of Blackton Bridge (989249), where it was previously quarried (see pl. 17A ;p.373). The Old Series Geological Survey Sheet 103 South West (New Series Sheet 32) also recorded it here and to the north east, but not on the adjoining Sheet 102 South East to the west. The dyke in Eggleston Burn is 28 feet wide (No.84) and follows the course of the Knotts Fault, trending north 60° east.

Approximately 600 yards to the east north east along the fault, the dyke is once more exposed in an old quarry (991261). Here it is about 36 feet wide and is apparently overlain by light grey baked shales. Lateral contact beds exposed in the southern wall of the quarry consist of fine grained, light grey, baked shales overlain by coarse pebbly grit of the First Millstone Grit lying south of the fault. The dyke is not exposed between this latter quarry and that in Eggleston Burn, but its presence is indicated by baked shales in an old quarry east of the Stanhope Road, which presumably worked the dyke rock.

Just over 2 miles to the east north east, at the southern end of the Ever Pools overflow, a massive fine grained buff sandstone is overlain by 35 feet of tough fine grained grey shales which appear to be baked, suggesting the proximity of the dyke, although it is not exposed. A short distance to the south the Knotts Fault continues its east north easterly run.

The next, and final exposure within this area, is east of Spurlswood Beck where some blocks of Whin can be seen in the forestry road leading down to The Grove (066298), once more on the course of the Knotts Fault.

In the 6-inch Geological Survey map the dyke was mapped along the crest of Pennington Rigg, occupying the line of the Knotts Fault. Afforestation activities, including the building of a grit road roughly along this line, now obscure any exposures of the dyke which may have previously occurred.

The Whin dykes have been described by Teall (1884, p. 209), Holmes and Harwood (1928, pp. 514 - 528), and Dunham (1948, p. 59). The latter described them as "for all practical purposes identical with Type 2 of the Whin Sill, tochylitic margins similar to Type 1 being developed at the side contacts."

THE CLEVELAND DYKE.

Commencing in the west, members of this dyke system are first encountered near the Bow Lee Beck - Wester Beck confluence at Mirk Holm (902298), forming a waterfall. The dyke here is bifid, as seen in Bow Lee Beck, each member being 4 feet wide separated by limestone belonging to the Three Yard Limestone, overlying sandstone. This screen of sedimentary rocks is 20 feet wide. Immediately to the north the top of the Scar Limestone is exposed along a fault contact (see p. 31). West of the stream the dykes can be traced over the small spur between it and Wester Beck. The northerly member is well exposed and bends sharply to the south for a few yards before resuming its west north westerly trend to cross the beck. It is well exposed in the beck and its steep western bank. The southern member is not exposed in the east bank of Wester Beck, but crops out in the west bank. The twin members coalesce a few yards further to the west north west in the stream which swings to the west upstream. There are no apparent metamorphic effects on the country rock.

Two parallel branches of the dyke occur in Red Grooves Level about a mile to the east. The members are 95 feet apart (Dunham 1948, p. 60). In Coldberry Gutter the dyke once more comes to view exposed in six isolated outcrops along the line of the Lodgesike - Manorgill Vein. The westernmost exposure reveals a 6 feet wide dyke running east - west for 40 yards before turning to follow a west south westerly course for a further 40 yards at its western end. In the remaining five exposures the dyke is largely obscured by debris, but outcrops of 40 to 80 feet in length occur. Any metamorphic effects of the dyke have been masked by mineralized processes.

The dyke is next encountered in the northern bank of the Tees 1 mile east of Middleton-in-Teesdale. Near the mouth of Howgill Sike the dyke, 10 feet wide, is exposed in the stream bed, trending east 30^{o} south. It appears not to penetrate the overlying Four Fathom Limestone at this point. It is again exposed to the east 15 yards from the mouth of the neighbouring unnamed stream. The thickness remains at 10 feet. From here it swings south eastwards for about 50 yards to the Tees and then turns to a course just south of east, being exposed in the north bank for a distance of 100 yards, followed by a gap of 100 yards, and a further exposure for 60 yards.

To the east, for distances of approximately 125 and 130 yards west and east of the mouth of Intake Sike respectively, the dyke is once more well exposed, presenting a cliff-like face in the latter outcrop. It is seen to be 27 feet wide in the sike, and follows a course roughly east 20° south.

About 400 yards further east, the dyke was once worked at Foggerthwaite Quarry ~~once worked the dyke.~~ It is exposed in the eastern end of the quarry, the sides being flanked by massive grit of the Low Grit Sill. A level was driven westwards beneath the road, opening out in shales on the steep eastern slopes of the Tees. The shales are fine grained, black, and baked, and occur on the southern upthrow side of an east - west fault, the course of which the dyke now follows. The dyke is poorly exposed below a shale tip.

In Eggleston Burn, 1,300 yards east north east, the dyke (No.89) has once more been worked (see pl. 17B ,p. 373). It is exposed in the western and eastern banks (where it was quarried) and in the stream bed, being 57 feet wide. In the east bank the shale below the High Grit Sill has been baked, and a 9 feet sandstone recrystallized.

The en echelon character of the dyke is spectacularly displayed in the Coldthron Nook - Woolly Hills area to the east. From Coldthorn Nook (024253) a narrow mound-like feature with scattered outcrops of the dyke runs east 25° south for about 560 yards. At its eastern end a parallel feature runs for approximately 280 yards immediately to the north, and overlapping the previous feature for 140 yards. The dyke was quarried at the eastern end of the second feature, loose pieces of dyke rock occurring in the quarry. Approximately 80 yards to the east, a third echelon unit runs in a parallel direction for 220 yards, again shifted slightly to the north. It has been worked in two old quarries, in which the dyke is exposed, being 60 to 70 feet wide. Near Woolly Hills the dyke is once more exposed in an old quarry retaining its thickness of 70 feet. Some overgrown quarries situated 200, 530, and 600 yards in an east south east line probably worked this echelon, which once more has a northerly shift.

Teall (1884,pp.209-227) described the Cleveland Dyke, while Holmes and Harwood (1929,pp.34-41) supplied chemical analysis and referred to the rock as a tholeiite of the Cleveland type. Dunham (1948,p.60) briefly describes the dyke as a porphyritic rock, with phenocrysts of zoned plagioclase with the inner zones labradorite up to An65, the outer zones oligoclase. Pyroxene phenocrysts include colourless enstatite and a coloured clinopyroxene, probably hypersthene - augite. Rod-like iron oxides and small plagioclase and pyroxene microlites also occur in a glassy mesostasis, which is devitrified in some places.

In Coldberry Gutter, one member of the dyke echelon has been sericitized (No.62), producing a fine grained compact whitish rock in contrast to the normal black tholeiite. Dunham (1948,p.119), quotes this as evidence in favour of a Tertiary age for the process of mineralization.

CHAPTER 8.

STRUCTURE.

GENERAL.

The Alston Block. - Kendall (1911), Marr (1921) and Versey (1927) have shown that the Northern Pennines have remained a morphological unit since early Carboniferous times. That it is bounded on the north, west and south by the Stublick, Pennine, Dent, and Craven Fault systems respectively, and divided into two complimentary halves, the Alston Block to the north and Askrigg Block to the south, by the Stainmore Syncline, has already been indicated (p. 1).

The structural history of the Alston Block and neighbouring areas has been dealt with by Trotter and Hollingworth (1928), Turner (1927, 1935), Shotton (1935) and Dunham (1933, 1948). Compared with the Carboniferous sediments in the Northumberland Trough to the north, those on the Alston Block are thin and far less affected by the post-Carboniferous earth-movements, which produced only gentle doming and tilting to the east. Dunham (1948, p. 75) has summarized the tectonic history of the Alston Block along the following lines:

1) North west - south east Caledonian compression folding the Lower Palaeozoic rocks in an east north east direction, with the development of east north east and west north west cleavages.

2) Early Carboniferous movement which progressively elevated the Alston Block relative to the Northumbrian Trough along the lines of the Stublick Fault in the north; relative to the Stainmore area along the Swindale Beck - Lunedale Fault in the south; and possibly along the Crowdundale Fault, although apart from the fact that it lay west of the Outer Pennine Fault,

nothing is known of the western margin of the block (Reading 1954, pp. 147-48).

3) Inter Carboniferous gentle warping of the block.

4) Hercynian north - south compression producing master joints on the block at north 20° - 25° west, north 60° - 70° east, east - west folds on the block, the Bewcastle Anticline to the north, and possibly the Stainmore Syncline to the south.

5) Hercynian tension depressing the Alston Block along normal north north west and east - west marginal faults.

6) East north east Hercynian compression resulting in the Cross Fell Inlier thrusts, the Burtreeford Disturbance, and tear faults north of the Stublick Fault. The Whin Sill and associated dykes were intruded at about the same time, though possibly slightly later than the Burtreeford Disturbance.

7) Rotation of the block relative to neighbouring areas producing tear faults in the Brampton District and north east folding on the Block at Hunstanworth and elsewhere.

8) ? Late Hercynian gentle domal uplift of the block and formation of conjugate vein-fissures in north north west, east north east, and east - west to west north west directions.

9) Tertiary intrusion of west north west tholeiitic dykes en echelon during differential sideways movement.

10) Tertiary uplift and tilting of the block along marginal north north west and east - west normal faults.

11) Small lateral movements in mineral veins producing more or less horizontally striated post mineralization slickensides.

The Teesdale Dome. - The broad structure of the Alston Block was described by Versey (1927, pp. 1-16) and termed the Teesdale Anticline. Dunham investigated the structure by means of contours drawn on the base of the Great Limestone, a method previously employed in a more general fashion by Hickling (1931, p.321). As a result Dunham suggested the name Teesdale Dome for a structure which he interpretated as a gentle assymetric dome truncated by the Pennine Faults (1948, p.64). The almost flat top of the dome lies beneath the headwaters of the Tees and Maizebeck, between Great Dun Fell, Mickle Fell and Cronkley Fell, with the base of the Great Limestone at 2,400 to 2,500 feet above O.D. To the north and east the beds dip away at an average of 130 feet per mile, the key horizon reaching 500 feet below O.D. beneath the western edge of the Durham Coalfield. To the south the beds rapidly dip into the Stainmore Syncline.

Trotter (1929, p.161), on physiographic evidence, suggested that the "Teesdale Anticline" was late Tertiary in age, being the result of elevation and folding of a peneplain developed after early Tertiary uplift. Dunham (1948, pp.64-65) disputes this on the grounds that the supposed peneplain at the crest of the dome cuts across beds belonging to the Middle Limestone Group, while to the north, east, and south it cuts successively across the Upper Limestone Group, the "Millstone Grit" and the Coal Measures. He in turn suggested that although additional warping may have taken place in Tertiary times, the dome was initiated at a much earlier period, probably during the Hercynian, as a counterpart of the Durham Coalfield basin, forming a barrier between the western and eastern areas of Permian sedimentation, which was perhaps planed down before Triassic times.

STRUCTURE OF THE PRESENT AREA.

The present area, as previously indicated (p.1) lies on the southern margin of the Alston Block, overlapping slightly onto the north eastern corner of the Stainmore Syncline in lower Lunedale. Situated, as it is, on the southern margin of the Teesdale Dome, the general dip of the beds varies from easterly to south easterly, modified locally by the effects of faulting and minor folding. The accompanying structure contour map (fig. 9) has been drawn relative to the base of the First Millstone Grit rather than the base of the Great Limestone which was adopted by Dunham (1948) for the Northern Pennine Orefield, and by Reading (1954) for the Stainmore Syncline. While it would have been advantageous in many respects to have followed their practice, it is thought better to adopt the present key horizon because of the wider surface distribution in this area. Its use therefore necessitates less assumption regarding thicknesses of contiguous strata, which is a distinct advantage in an area with rapid lateral thickness variations. Bearing these lateral variations in mind, it will be realized that the structure based on the First Grit will be slightly different from that based on the Great Limestone, the main thickness variations occurring between these two horizons.

In addition to the base of the First Grit itself, various horizons were employed in constructing the map. Above the grit the bases of the various grits were utilized, there being only one marine horizon, of limited extent. Calculation on these horizons is accurate to within 50 feet. Below the First Grit most of the principal marine horizons were used up to and including the Crag Limestone, above this recourse had to be made to the base of the Low Grit Sill, the base of the Transgression Beds Grit and the Grindstone Sill. Thickness variations increase the margin of possible error to as much as 100 feet as we descend in the succession.

<u>Minor Folding.</u> - The general easterly tilt of the area is borne out by the fall of the structure contours to the east in the map, the key horizon occurring at a height of 2100 feet O.D. in the west, and at 700 feet O.D. in the east. This represents a fall of 1,400 feet in approximately 9 miles, or 1 in 34. This general dip is considerably modified in various places by gentle folds, complex faulting and minor folding intimately associated with the various faults. The broader fold structures are dealt with in this section, the faulting and associated minor folds in a subsequent section to avoid confusion.

Most of the broader folds were not detected as such in the field because of their gentle mature. South west of the Flushiemere Great Vein there is a gentle southwesterly dip amounting to about 1 in 17. The contours run north west - south east almost parallel to the Vein, but swing to north - south near the Lodgesike - Manorgill Vein. North east of the Flushiemere Great Vein there is an anticlinal fold with a north - south axis. The throw of the vein decreases rapidly to the south east so one would expect the deviation in trend of the contours on either side of the vein. It would appear that the faulting antedates ?
the folding, the increasing north westerly throw modifying the north - south trend of the contours on the western limb of the anticline. The axis of the upfold lies slightly west of the crest of the Flushiemere - Hudes Hope divide and has an amplitude of about 200 feet. Dips on the flanks of the anticline amount to 1 in 15 to the west, and an average of 1 in 30 to the east.

To the east a second upfold trending north - south then south south east and pitching southwards interrupts the easterly tilt. Its axis lies over Great Eggles Hope. The amplitude is about 100 feet with dips to the east and west of 1 in 30 and 1 in 20 respectively. To the south, the fold is pinched out, at this horizon (Transgression Beds Grit to First Grit) north of the Lodgesike - Manorgill Vein. Minor folding intimately associated with faulting further modifies the regional trend to the east, but these are more conveniently dealt with later (pp. 400 - 401).

A north ~~west~~ east trending fault north of Monks (which carries the main throw of the Lodgesike Manorgill Vein -see pp. 397 - 398) cuts across the pitching anticline, throwing about 130 feet south east. The axis of the fold, which is still manifest in the Fourth and Third Grits has turned to a slightly west of north trend. On the south west it is cut off by the north west fault from Lodge Sike to Knotts so that its western limb is very shallow. The amplitude, measured on the western limb, is less than 100 feet. It has a westerly dip of 1 in 10, accentuated no doubt by the effects of the faulting. To the east, the dip is about 1 in 23, becoming shallower as the regional dip is resumed.

South of the Lodgesike - Manorgill Vein and south west of the Lodgesike to Knotts fault, the James's Hill and Great Eggles Hope folds have converged, pitching southwards to form a bilobed dome extending over Hardberry Hill Allotment and Hudes Hope. The amplitude of the dome is in the neighbourhood of 500 feet. To the south the identity of the dome is lost in a series of north west - south east faults, while on the south west it is terminated by the Northern Teesdale Fault. Dips off the dome amount to about 1 in 17 to the south and south east, decreasing southwards to approximately 1 in 35 south and south east. To the west the beds dip at about 1 in 30 from the crest, with the contours gradually swinging around to a north east - south west direction, where the doming does not completely mask the regional dip.

In Red Grooves Hushes, north of the Lodgesike - Manorgill Vein, a small east - west anticline is exposed in the Great Limestone, north easterly and south easterly dips being recorded. This anticline is on too small a scale to be brought out satisfactorily by the 100 feet contour interval. Dunham (pp. 69, 300 - 301) noted this anticline and reports its easterly extension in Coldberry Mine south of the vein, which lies obliquely across its axis. The amplitude of the anticline is given as over 100 feet in Hudes Hope. This anticline no doubt represents the steeper part of the dome under Hardberry Hill. Dunham (1948, p.69) suggests that the anticline continues on its east - west course across the "Millstone Grit" country towards Woodlands. The present contour map does not support this, and it is suggested that the 'anticline' is terminated near the north west - south east fault from Lodge Sike to Knotts (but not necessarily by it, see p. 409).

East of the dome the easterly tilt is the predominant structural feature, but is accompanied by a gentle synclinal fold trending roughly east - west. The broad structure therefore is of a gentle syncline pitching slightly to the east at an average rate of 1 in 30. The syncline is terminated on the south by the Northern Eggleston Fault, part of the Lunedale - Butterknowle Fault system. This simple structure is somewhat modified by faulting, including the Knotts and Black Hill faults (see pp. 401-

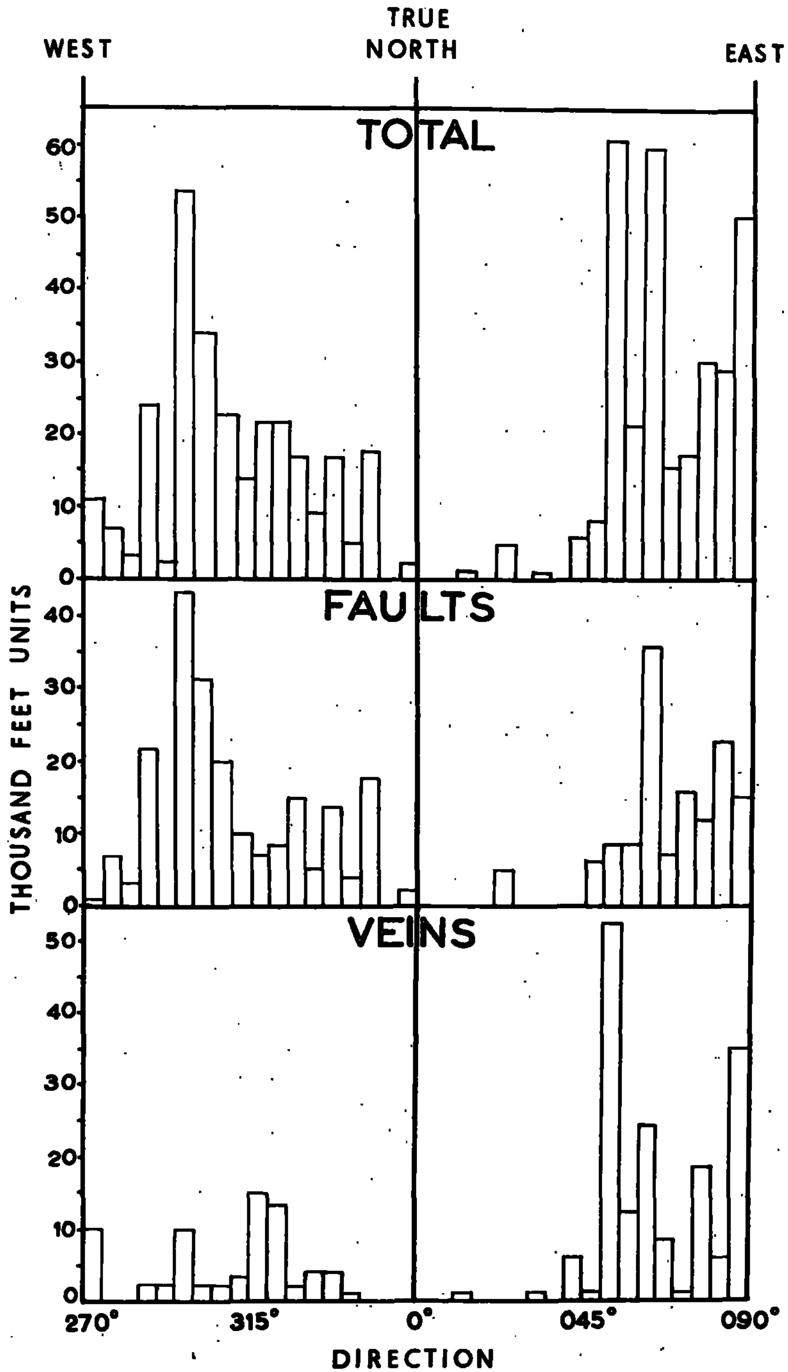
402, 396). A feature which is inadequately portrayed by the 100 feet contour interval is the downwarping beneath the incoming Second Grit. Even with this interval some indication is given, however, of the steepening dip beneath the incoming grit on Hamsterley Common (between the 900 and 800 feet contours), and north and south of Knotts Fault (between the 1,000 feet and 900 feet contours).

South of the Northern Eggleston Fault the beds dip steeply northwards at about 35^{o} or 1 in 1.5 while south of the Southern Eggleston Fault the dip is southerly or south westerly, towards the Stainmore Syncline, at an average of 1 in 20. This assymetrical anticlinal fold is further complicated by a plexus of faults, with the east - west to east north east Southern Eggleston Fault running roughly along its axis. There is an anticlinal fold on the southern side of the Butterknowle and Wigglesworth faults (Dunham 1948, p.63), to which system the Northern Eggleston Fault belongs. Hickling (1950) has shown that the Butterknowle Fault runs in a syncline between two upfolds, both of which have steeper northern limbs, similar to the anticline south of the Northern Eggleston Fault.

Generally speaking, south of the Lunedale - Southern Eggleston Faults the beds dip in a southerly direction into the Stainmore Syncline. This is modified however by a subsidiary synclinal fold trending north - south, due in the main, probably to the effects of faulting (see pp. 405-406).

South west of the Teesdale Fault, the general dip is north easterly at about 1 in 15. Between the two branches of the fault the contours are modified by the increasing north westerly throw, resulting in an east - west to west north westerly trend.

STATISTICAL ANALYSIS OF STRUCTURAL TRENDS



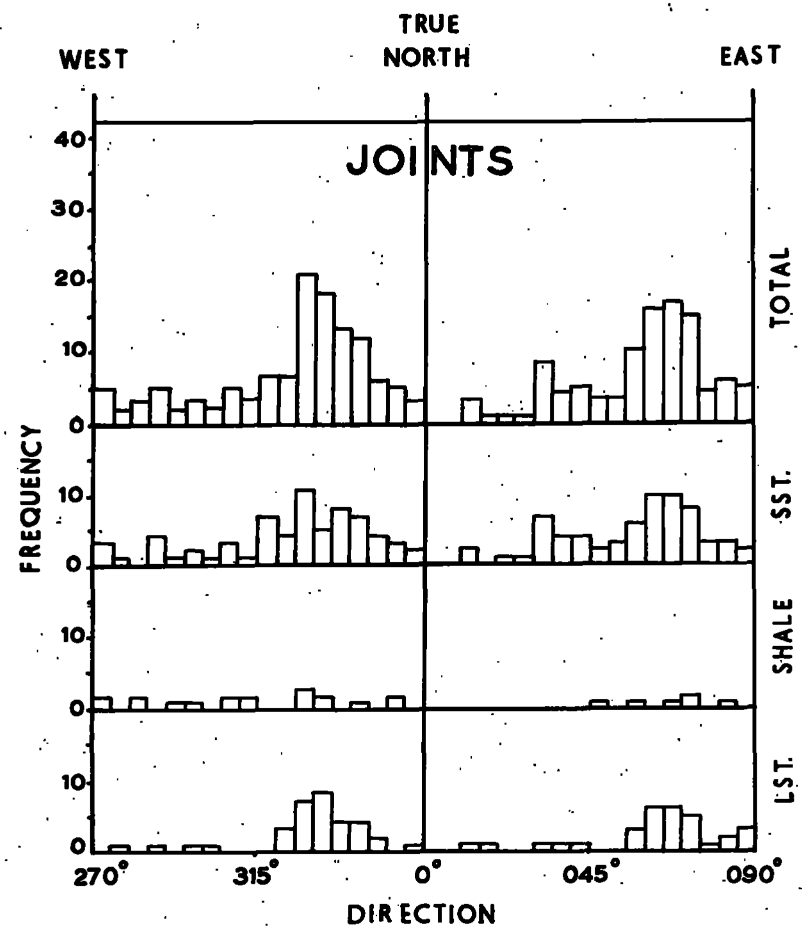


Fig. 10

To the south east, as we approach Lunedale, the contours swing through a right angle between the Teesdale and Lunedale Faults, dipping south east to south into the Stainmore Syncline.

Faulting and associated Folding. - Dunham (1948, pp. 65-70) has discussed the faulting of the Alston Block dividing them into a dominant north west direction spreading over a considerable angular range, but with a maximum at north 25° - 35° west; another maximum in an east - west direction; feebler faulting in an east north east direction; and a few faults trending nearly north - south. Only faults with displacements of over 40 feet were considered, few of which carried mineral deposits. The great majority of mineral veins have throws of less than 40 feet.

With regard to the vein fissures, the orefield is remarkable for the conjugate pattern which it exhibits. The major trend of the productive veins is east north east with a strong maximum at north 50° - 60° east. This group is cut by cross veins (seldom strongly mineralized) trending north 25° - 30° west. An additional set of cross veins trending north 45° - 50° west intersect these at a small angle. The conjugate angle is bisected by a second set of productive veins, the "Quarter Point" Veins, varying from east - west to north 65° west.

The present statistical analysis includes both mineralized and non mineralized faults, and one combined analysis. No differentiation has been made on the degree of throw in the various faults, but merely on whether or not they are mineralized (see fig. 10, p. 386). Histograms have been constructed showing the length in units of 1,000 feet, at 5° intervals, all the faults and veins mapped being included.

Faulting occurs in three major trends, north west - south east, east north east, and east - west, with strong maxima at north 55° - 65° west (the dominant direction), and north 60° - 65° east, and lesser maxima at north 80° - 90° east and north 70° - 75° west. The mineral veins show similar strong east north east and east - west trends with maxima at north 50° - 65° east and north 75° - 90° east. The north west trend is far less well developed, with minor peaks at north 35° - 45° west and north 60° - 65° west, while a small peak at north 85° - 90° west may be included with the east - west veins. The major peak at north 50° - 65° east corresponds with Dunhams analysis for the Northern Pennines as a whole, the east - west maximum with his 'Quarter Point' Veins whose trend varies from east - west to north 65° west (p. 70). His peaks at north 20° - 35° west and north 45° - 50° west are replaced by the minor peaks at north 35° - 45° west and north 60° - 65° west, representing a deviation of 15° west in each case. The combined analysis shows three well defined peaks, at north 50° - 65° east, north 60° - 65° west, and north 85° - 90° east.

For the sake of convenience, the faults and veins are described together, under two headings: north west to north north west Faults and Veins, and east - west to north east Faults and Veins, the latter because east - west, east north east, and north east trends frequently alternate.

North west to north north west Faults and Veins, and associated minor folding. - The Teesdale Fault is the most striking of the north west faults. North west of Teesdale it continues in Cumberland, beyond Alston, known variously as the Harwood Fault, Sir John's Vein, and Park Fell Vein, and beyond this as the Faugh Cleugh Fault (Dunham 1948, p. 67). In that part of Teesdale mapped it takes the form of a double fault, the Northern and Southern Teesdale Faults, producing the prominant Whin Sill scarp on the south western side of the dale. The total throw of the twin fault is about 320 - 300 feet north east in the southwestern part of the area. The Southern Teesdale Fault, which has an approximate north easterly throw of 200 feet in the Holwick - Crossthwaite Quarry area, dies out rapidly to the south east. The downthrown Whin Sill north east of the fault rises rapidly in that direction until, approximately 300 yards west of the disused Middleton Quarries, it is on a level with the sill south west of the fault. This can be clearly seen in the Frontispiece. The Northern Teesdale Fault, with a north easterly throw of about 120 feet in the neighbourhood of Scoberry Bridge (910274), continues south eastwards to the limit of the area mapped, the throw increasing to about 160 - 200 feet in Lower Lunedale where the top of the Scar Limestone occurs south west of the fault at a height about level with the horizon of the Four Fathom Limestone north east of the fault. The fault is slightly mineralized, as evidenced by outcrops of White Whin in Unthank Bank and the south bank of the Tees at Breckholm Pool, along the line of the fault.

The line of the Southern Teesdale Fault is clearly exposed along its course in the present area in the bold Whin Scar. The Northern Teesdale Fault is exposed in three places along the right bank of the Tees, at Unthank Bank, in Park End Beck, and at Breckholm Pool (see pp. 33-34). Beyond this the precise course of the fault is inferred.

Further north, a third, parallel fault, also downthrowing to the north east, has been mapped in Stony Gill and the Tees near Middleton Bridge. In the latter locality it brings the top of the Five Yard Limestone near the base of the High Brig Hazle, involving a throw of about 10 - 15 feet. To the north west it is responsible for the faulting out of the Three Yard Limestone south east of Brokersgill Sike, which apparently it does not reach. To the south east it has been mapped as far as the River Lune, whereabouts its throw has increased rapidly to about 80 feet north east (unless the Lonton Quarry Limestone has been misidentified (see p. 128)). This deduction is based on the fact that south of the proposed line of the fault, the base of a limestone regarded as the Great Limestone occurs at about 800 feet O.D. in Lonton Quarry, dipping east at 15°, whereas north of the fault the Three Yard Limestone dips due north at 25°, at 750 feet O.D. Beyond the Lune the course of the fault cannot be mapped because of a thick drift cover.

A fourth, subparallel fault crosses Hudeshope Beck approximately 70 yards north of Hude Bridge. It throws about 60 feet south west bringing the High Brig Hazle level with the limestone above the Three Yard Limestone. The fault itself is not exposed, but the Three Yard Limestone outcrops in the left bank 30 feet above stream level north of the fault, while to the south the top of the succeeding unnamed limestone crops out in the stream dipping north east. The fault is lost sight of to the north west and south east, but at Laky Hill, a Great Limestone outlier dipping north west at 18° is let down between two faults, which probably represent the continuation of the fault. Just over 80 yards to the north of the limestone, Bridge Sill is made up of the Low Brig Hazle at stream level, involving a throw of about 150 - 200 feet south. South of Laky Hill, the Low Brig Hazle is once more exposed in the Tees, which of necessity implies a fracture throwing a similar amount to the north. These two faults have been mapped as converging to the west of Laky Hill, the combined fault continuing north westwards to join that exposed north of Hude Bridge. The southerly fault cannot run east - west because the Low Brig Hazle is exposed in both banks of the Tees to the west, and again below Middleton Bridge to the west north west. The only possible course is north westerly. The northern fault must of necessity follow an east - west trend, exposures in the Tees to the east rule out a north easterly trend, while a fault of this magnitude would have obvious effects in the country to the north west. The fracture can in fact be picked up once more to the east in Foggerthwaite Quarry and the Tees.

In Intake Sike the Four Fathom Limestone crops out in the stream near the 700 feet contour. Approximately 500 yards to the south east, Red Scar Quarry worked the Great Limestone which lies below 700 feet O.D. The Great Limestone crops out once more about 250 yards to the north west in the hill side, again below the 700 feet contour. It would seem then that the east - west fault runs between this point and the Four Fathom exposure in Intake Sike. However, about 30 yards north west of the final Great Limestone exposure, 6 feet of massive coarse grit outcrop at stream level in the north bank of the Tees. The Tuft, exposed to the south east in the Tees, is flaggy and fine grained, while no lower lying sandstone is coarse grained. The situation is clarified somewhat when we examine sections along the line of the fault in Foggerthwaite Quarry. This quarry worked a member of the Cleveland Dyke which occupies the fault at this point. North east of the road the quarry walls consist of the Low Grit Sill. South west of the road the Low Grit Sill is seen to be downfaulted on the north against shales below the grit on the south, involving a throw of 10 - 15 feet. From this it can be concluded that the coarse grit faulted against the Great Limestone to the west at river level, is one of the Coal Sills, probably the Low Coal Sill. The east - west fault would therefore seem to have undergone a reversal of throw. The fault peters out to the east on Foggerthwaite.

This reversal in throw is largely accounted for by a north north west - south south east fault running between Whistle Crag and Intake Sike. In the sike the Great Limestone, although not exposed must lie quite near the 800 feet contour (see p. 120), while just over 450 yards to the south east it crops out below ~~the~~ 700 feet O.D. The primary surveyors explained this by a reasonably steep dip. Dips of only 5° south east occur in the Tuft below Red Scar Quarry, while in Intake Sike northerly dips of 13° and 3° occur. These facts together with the proven presence of an east - west fault which, where exposed throws to the north, necessitates the presence of a north north west fault with a north north easterly throw of about 100 feet. Further evidence is obtained north west of Whistle Crag. The High Grit Sill is exposed in Whistle Crag and beyond while about 130 yards to the north west at the same level, a sandstone with a shelly top identifying it as the High Coal Sill (see pp.120-21) dips south east at 20°. Allowing for the dip this entails a throw of about 80 feet, indicating that the throw decreases to the north west.

The fault gradually swings to a north westerly trend with diminishing throw, finally petering out near Black Edge (962261). The diminishing throw is due largely to the influence of the east north east Knotts Fault which joins it near the High Coal Sill quarry and which upthrows north north west. Whether the north north west fault coninues south south eastwards beyond the east - west fault from Laky Hill is not known. It has been mapped as far as Black Edge on the evidence of the fading out of the High and Low Grit Sills features (see pp. 151-152).

The Flushiemere Great Vein represents the southward continuation of the Swinhope fault belt of Weardale (Dunham 1948, pp. 68, 295). The northern part of the vein, in this area, is twin, first being seen near the Flushiemere Beck - Rowantreegill Sike confluence, where the downthrown Great Limestone is exposed in both streams. To the south the Great Limestones gives rise to a feature running southwards to Bales Hush, the south westerly upthrow being about 60 - 70 feet. A series of old lead shafts which worked the vein help to mark the run of the fault. To the south east the vein interrupts the southerly run of a feature containing the Knucton Shell Beds, and in a more spectacular fashion the features of the Coal Sills and Pattinson Sill, which are truncated on the north east to form pear-shaped prominences on the spur between Flushiemere Beck and Bleagill Sike. The fault is once more exposed in Bleagill Sike where one of the Knucton Shell Beds is downfaulted against shales in the Coal Sills, involving a south westerly throw of between 60 and 80 feet. South east of the sike, the prominent Coal Sills and Pattinson Sill features running north eastwards below Bleagill Allotment end abruptly against the fault, while the southerly run of the Low Grit Sill feature is likewise interrupted. The fault continues south eastwards to Lord's Allotment where it splits, the northerly branch swinging eastwards towards Coldberry Grains interrupting the Low Grit Sill feature below Coldberry Moss. The fault peters out from a throw of about 30 feet south to nil in Coldberry Grains. The southerly branch of the vein trends south south east and has been worked by some old lead shafts. Dunham (1948,p.68) suggests that the vein may be represented in Skears Mine by No. 2 Cross Vein which throws 60 to 100 feet south west. In view of the petering out of the northern branch of the vein, and the absence of any such faulting in the northern side of Coldberry Gutter, there seems little likelihood of this being so.

At Bleagill Bridge (912299), the Iron Post Limestone crops out in Bleagill Sike at about 1,275 feet O.D. About 200 yards to the west, in Bow Lee Beck, shales above the High Brig Hazle crop out at approximately 1,250 feet O.D. Dips in both localities are very low. The Iron Post Limestone is on a level approximately the same as the Three Yard Limestone west of Bleagill Bridge, which involves a throw of about 80 to 100 feet to the east. No exposures occur between the two described because of thick drift. The fault, which must exist, has been drawn in following a roughly north west - south east course.

A number of north west trending veins occur south east of Coldberry Gutter, the most important of which structurally are Skears No. 2 Vein mentioned above, and Hall's Vein, which throws about 60 feet north east (Dunham 1948, p.305). This latter is exposed in Hudes Hope Beck, in the right bank of which Low Skears Level was driven to work the vein. In the beck the throw as seen in the Great Limestone, is about 60 feet north, bringing the limestone against the Iron Post Limestone and associated beds (see p. 112). To the south east the fault peters out, as it does not affect the bold Low Grit feature and underlying features below Brown Dodd.

East of Hudeshope Beck, below Monks Moor, a north west - south east fault can be mapped from Cat Level to Knotts Hole, east of Eggleston Burn. Its presence is first betrayed by the northerly termination of the Grit Sills and Transgression Beds Grit features of Brown Dodd. It is located once more to the south east in the headwaters of Snaisgill Sike where it brings the green sandstone and associated beds on the north east level with the First Grit on the south west, involving a south westerly throw of about 40 feet. Further east it brings the Middle Grit level with the top of the First Grit north of Raven Hills, and in Horden Allotment can be seen to throw the features of the First Grit, Grindstone Sill, and Transgression Beds Grit down to the south west about 20 feet. From here it is lost sight of until Eggleston Burn, where it throws the Low Grit Sill up about 30 feet to the north. It is next seen to interrupt the Fourth and Fifth Grit features near Knotts Hole, before terminating against the east north east Knotts Fault.

North of Cat Level the base of the Low Grit Sill feature is terminated at a height of about 1,375 feet O.D. North east of the fault, in Marlbeck Gutter, the base of the grit is exposed at about 1500 feet O.D., which indicates a north easterly upthrow of about 125 feet. The disparity of throw between this point and to the south east, is explained by the presence of a fault which joins the north west fault near Cat Level and runs north eastwards to Great Eggles Hope, and which has a fairly considerable south easterly throw. The north west fault, therefore, must continue northwards to join the Lodgesike - Manorgill Vein, carrying in this part the main throw of the latter, which is then transferred to the north east fault. This however is more fully dealt with in the next section (p. 398).

East of Eggleston, the Northern and Southern Eggleston Faults bound a structurally complex area which has already been described as the steep northern limb of an anticline. This limb is further complicated by a plexus of faults, trending from west north west to north north west. Along Redmire Gill a west north west fault throws west south west about 50 to 60 feet bringing the First Grit on the south level with the Grindstone Sill on the north. Between this fault and the Southern Eggleston Fault to the south, two north north west faults occur. The westernmost of these runs from Stobgreen Sike to the head of Adders Gill, throwing about 80 feet north north east and bringing the Grindstone Sill on the east about level with the top of the Hipple Sill on the west. The easterly fault throws in the same direction but only about 10 feet.

On Barnard Castle Allotment a north west - south east fault throwing north east has been mapped on the evidence of interrupted Millstone Grit features. The steep northerly dip of the beds makes calculation of the throw difficult, but it is estimated at about 40 feet. About 1,000 yards to the east, another fault, trending north north west - south south east, once more throws north north east, disrupting the Millstone Grit features. The approximate throw is 60 feet bringing the base of the Fifth Grit feature on the east level with the base of the Fourth on the west.

North of this fault belt, a north north west fault throws 10 - 20 feet north north east bringing Coal Measures against the Fifth Grit, and them swings north westwards on Grey Carrs towards the Knotts Fault.

Finally, in the relatively undisturbed area of Hamsterly Common a fault runs north north west across Black Hill, spectacularly interrupting the Millstone Grit features. It is exposed in South Grain Beck immediately east of The Loop, where it throws the Grindstone Sill about 30 feet to the east. The fault is terminated on the south, by a second which runs roughly east - west along Euden Beck. This latter, which throws south about 20 - 30 feet is accompanied by a small east - west synclinal fold superimposed upon the broader syncline already described in this area. The fold dies out rapidly to the east, as does the fault.

<u>East - West, to North East Faults and Veins, and associated minor folding.</u> - These trends are more conveniently treated together as they frequently alternate in a single vein or fault.

One of the most striking east - west to east north east veins in the area is the Lodgesike - Manorgill Vein. It is first located in Bow Lee Beck as an east - west fault with associated limonite mineralization 70 to 80 feet wide. North of the fault, shales immediately below the Five Yard Limestone occur, on a level with the High Brig Hazle south of the fault. A southerly downthrow of 46 feet is recorded by Dunham (1948,p.300). A dip of 8° east of north was recorded in shales north of the dislocation. A level was driven eastwards along the mineral vein.

To the east the fault is lost beneath thick drift for a distance of ½ mile. Its effect can be judged from the displacement of the Great Limestone from a height of about 1,325 feet O.D., immediately north of the fault, to approximately 1,225 feet O.D. to the south. Its effects are more spectacularly displayed in Red Grooves Hushes, where, at the eastern end, the Pattinson Sill on the north is brought above the Crag Limestone on the south, indicating a southerly downthrow of about 80 to 90 feet at this point. Minor folding in the form of an east - west anticline associated with the fault has already been discussed (p. 384). To the east the vein has been worked open-cast in Coldberry Gutter (see pl. 1, p. 7). In the northern side of the Gutter, north of the vein, beds from the Crag Limestone to the Low Grit Sill are exposed, while beds from the latter to a limestone possibly representing the Rookhope Sheal Beds on the Lower Felltop Limestone crop out in the southern side. To the east, the fault, now following an east north east course, is exposed in Longmire's Gutter, 500 yards north north east of its junction with Hudeshope Beck. The Great Limestone on the upthrow side is brought in contact with shales and sandstone possibly near the horizon of the Little Limestone (Dunham 1948, p.301). No mineralization can be detected here. Followed east north eastwards the surface effects of the fault are lost sight of until we reach the crest of the Hudes Hope - Great Eggles Hope divide where the Transgression Beds Grit can be seen to be upthrown to the south approximately 20 feet or less. There is little doubt concerning the identity of the coarse grit exposures north and south of the fault (see pp. 174 -176). The Lodgesike - Manorgill Vein has apparently undergone a rapid reversal of throw. Dunham (1948, p.301) states that the Knucton Shell Bed on the south is brought against one of the Grit Sills on the North 600 feet from the portal of Lodgesike Low Level. Depending upon the identity of the grit this involves a southerly throw of anything from 10 to 100 feet. It is here suggested that the throw is relatively small, that the grit is the Low Grit Sill, and that the main throw of the fault is carried along the north north west fault running towards Cat Level (see p. 394). A cross cut, running north, out from Marlbeck Vein to LodgeSike, met at a distance of 850 feet a fault which brings the Great Limestone into the level (Dunham 1948, p.301). The position of this fault roughly corresponds with the proposed line of the north north west fault and may in fact be that fault. The throw is given as 105 feet south.

Near Cat Level an east north east to north east fault has been mapped running north west of Monks and joining the Lodgesike - Manorgill Vein west of Great Eggles Hope Beck and thence running east north east as the Dusty Gill - Flake Brig Vein. This fault brings the First Grit on the south level with the Transgression Beds Grit on the north, indicating a south easterly throw of about 130 feet. The Lodgesike - Manorgill Vein complex continues east north east to Manorgill, with one branch running east - west, then east north east to join the Dusty Gill - Flake Brig Vein. There is no apparent southerly downthrow of any magnitude until it is joined by the north east fault described above, when the Dusty Gill Flake Brig Vein, runs east north eastwards with a large southerly throw. The effects of minor faulting, with north east and south easterly dips are evident in Manorgill Hushes, but the overall effect is of southerly uplift. Manorgill North Vein runs east - west from Pikestone to Manorgill, having no apparent effect on the Grit Sills and Transgression Beds Grit features on eastern Hudes Hope. It has a recorded throw of 16 feet south at Manorgill Mine Dunham (1948, p.300).

The effects of the Dusty Gill - Flake Brig Vein are seen in Great Eggleshope Beck, where the Firestone Sill on the north is brought against the High Grit Sill on the south. To the east north east it interrupts the features of beds from the Grit Sills to the First Grit on the north, and from the Transgression Beds Grit to the Fourth Grit on the south. It is exposed in Dusty Gill where the Transgression Beds Grit on the north is faulted against the beds just below the First Grit on the south, indicating a southerly throw of over 100 feet. Just west of Little Eggleshope Beck, it joins a short east - west vein and then swings north east to join the East Rake Hush Vein to form Sharnberry Vein. The Sharnberry section of the vein carries the main throw, a southerly throw of 105 feet being recorded at Sharnberry "B" Shaft, while the East Rake Vein has a north west throw of 10 feet (Dunham 1948, p.310). The effect of the latter, which has been hushed in East Rake Hush and worked in East Rake Lead Mine, is best displayed in Little Eggles Hope, where it brings the top of the Grindstone Sill down 10 feet to stream level on the north.

In Little Eggleshope Beck the Flake Brig Vein throw is also seen to good advantage, here it brings the First Grit on the south against the Upper Felltop Limestone on the north.

Near Sharnberry "A" Shaft (005314), the Sharnberry Vein splits into two branches (Dunham 1948, p.310), which can be traced across the fell by means of old shafts. The southern branch, which carries the main throw, continues north east to South Grain Beck where it downfaults the First Grit to the south. On the north branch a strong east - west fault, in line with the Little Eggleshope Vein was encountered, while both branches were traversed by a north north west cross course, probably a continuation of the Cornish Hush Vein (Dunham 1948, p.311).

The Little Eggleshope Vein runs westward from the Cornish Hush Vein, throwing south and bringing the Fourth Grit of Jack Scars against the Middle Grit on the north. From Jack Scars it swings west south west to just beyond Great Eggleshope Beck, with a southerly throw of 84 to 98 feet (Dunham 1948, p.307). In Little Eggles Hope it brings the top of the First Grit near the base of the Grindstone Sill, while to the west on Round Hill, it displaces the Transgression Beds Grit about 40 feet south. Still further west it splits into 3 or 4 minor faults which are exposed in Great Eggleshope Beck (see pp. 142 - 143).

The westerly decrease in throw is probably in part due to a curved fault running from near the head of Wiregill to join Flake Brig Vein west of Little Eggles Hope. This throws north east bringing the base of the First Grit level with the base of the Grindstone Sill on the eastern slopes of Wiregill and involving a throw of about 40 to 50 feet.

Associated with the Little Eggleshope - Flake Brig Veins there are a number of minor folds. Bordered on the north by the Little Eggleshope Vein, on the south by the Flake Brig Vein, and on the north east by the curved fault, a small anticlinal fold modifies the regional tilt. Its north north east axis lies over Wiregill, with an amplitude of less than 100 feet. Dips on the eastern and western limbs are 1 in 15 and 1 in 14 respectively.

North of the Little Eggleshope Vein, a similar upfold trending north north east occurs north of Jack Scars. Its amplitude is less than 100 feet, with dips of 1 in 20 and 1 in 15 to east and west respectively. South of the vein this fold pitches south, dying out about 500 yards to the south. Its amplitude is about 50 - 75 feet, but it is not brought out by the 100 feet contour interval. Dips to east and west respectively are 1 in 13 and 1 in 25.

South of Coldberry Gutter, a number of north east trending veins occur, including the High Stable Edge - Hardberry Vein which has a north west throw of 15 - 25 feet (Dunham 1948, p.302) in its north eastern part, but which changes throw towards the south west, bringing the Great Limestone down to the south east about 10 - 15 feet near Stable Edge.

To the south Ravelin Old Veins, downthrowing 21 feet and 14 feet to the south east respectively, join to the north east to form Lead "C". Still further south the Ravelin - Hunt's Coldberry Vein has a displacement of 6 feet north west at Ravelin and a 40 feet north west throw at Skears Great Rise near which it is joined by Lead "C".

Of these veins only the High Stable Edge - Hardberry Hill Vein and the Ravelin Vein can be located with any certainty on the surface. The former can be seen to displace the Great Limestone to the south east on Stable Edge, and the Grit Sills to the north west at High Stable Edge. The Ravelin Vein is exposed in Brokersgill Sike where it cuts through the Great Limestone.

An east north east to north east fault, the Knotts Fault, runs from north of Whistle Crag (977252), where it abuts against a north north west fault described previously (p. 391), to the south of The Grove (066298) at the eastern limit of the area mapped. It is first seen in Eggleston Burn near Cowlake Bottoms where the Low Grit Sill is upthrown to the north against the High Grit Sill on the south, involving a throw of 80 - 100 feet south. The fault can thence be traced east north east through the quarry north of Moor House where the First Grit is brought down on the south level with the Transgression Beds Grit on the north, an approximate throw of 100 feet. From here it runs east north east to the tributary of Quarter Burn, where it brings the base of the Fifth Grit a little below that of the Fourth Grit, a southerly throw of about 70 to 80 feet. To the east north east the course of the fault is largely obscured by drift and afforestation activities but it is located once more in Spurlswood Beck about 800 yards south west of The Grove. The southerly throw here is somewhat reduced, being 30 to 40 feet, bringing the top of the Grindstone Sill on the south level with beds below the sill on the north. The Geological Survey map the Whin Dyke (which occupies the course of the fault) north east from here, but show no displacement along the line of the fault after about 400 yards east of Spurlswood.

The Lunedale Fault is one of the most important faults in the area. It is one of a series of linked faults flanking the northern side of the Stainmore Syncline, The Swindale Beck, Lunedale, Butterknowle and Wigglesworth Faults. Of these the three latter throw south, but there is evidence that the Lunedale Fault formerly threw to the north, the beds dipping steeply north on the upthrow side (Dunham 1948, p. 63). The main fault was certainly in existence before the intrusion of the Whin Sill but there is evidence of later movement, (Dunham 1948, p. 63).

Dunham (1948, p. 64) suggests that the Swindale Beck Fault represents a hinge line active in Lower Carboniferous times, separating the stable Alston Block from the adjacent, more rapidly sinking Stainmore area.

Within the present area the fault is first exposed in the Tees at Eggleston, where it splits into two faults, the northern branch following a north east course, the southern branch an east - west to east north east course. For the sake of convenience these two faults are referred to as the Northern and Southern Eggleston Faults. The Southern Eggleston Fault brings the Four Fathom Limestone on the north against the Transgression Beds Grit on the south, in the left bank of the Tees north of Eggleston Bridge. This indicates a southerly throw of about 300 to 325 feet. To the east it brings the base of the Transgression Beds Grit feature in the north above the base of the Hipple Sill on Folly Bank, involving a southerly throw of 100 to 150 feet. The decrease in throw compared with that in the Tees is in part accounted for by a north north west fault which joins the present fault near Nab Gill. This fault, as exposed in the gill, has a westerly throw of about 80 - 100 feet, bringing the shales below the Transgression Beds Grit on the east against the Hipple Sill on the west. To the south the fault has a westerly throw of 40 feet in the Tees at Black Sills (see p. 157).

The Southern Eggleston Fault continues eastwards, running along Goose Tarn Beck. East of the first north north west fault previously discussed (p.395) the throw of the fault is greatly modified by the easterly displacement of the north north west fault, so that the Grindstone Sill is exposed on both sides of the beck. The second north north west fault to the east cancels the effect the Southern Eggleston Fault. To the east it is exposed in Pallet Crag Gill where the top of the Grindstone Sill dips north west at 50° into the disturbance. A short distance upstream shales above the sill crop out dipping north at 20°, proving that the throw is very small. About 500 yards east of the beck, the First Grit feature is displaced by the fault, being downthrown about 10 feet south. Beyond this the fault is lost sight of within the area mapped, but was traced as far as Evenwood (155250) by the primary surveyors.

North east of Eggleston the First Grit feature running south east from Nemour Hill is displaced in the headwaters of Stobgreen Sike and the grit upthrown to the south east. The structure is complicated by the Redmire Gill fault, throwing south south west. North of this latter the beds dip steeply northwards at 35 to 37° towards the Northern Eggleston Fault, which in effect increases the southerly throw of the latter to the east north east. Thus the First Grit on the north is faulted in turn against beds ranging from the First Grit to the Fourth Grit as we move east north east. The north west fault in Barnard Castle Allotment throwing approximately 40 feet north, east, increases the southerly throw of the Northern Eggleston Fault to about 35 feet. It is further increased by the north north west fault to the east to about 400 feet. The disturbance continues north eastwards to join with the Butterknowle Fault south west of Woodlands, beyond the limits of the area mapped.

South westwards from Stobgreen the fault is largely lost sight of, but the Grit Sills feature running south eastwards from Blackton Beck dies out near Holy Trinity Church. This is probably due in the main to the attenuation of the grits, but the effect of the fault, which throws north west here, no doubt plays a part. The Four Fathom Limestone, exposed in the Tees at about 600 feet O.D., dips south east at 6°, but is not seen to the north east, and certainly does not reach the surface in Eggleston Burn where the top of the Great Limestone crops out at about 675 feet O.D. This strongly suggests that the fault continues south westwards, running north of the Four Fathom Limestone exposure.

Near Town Head the Northern Eggleston Fault gives off a branch running east north east with a throw of about 30 feet south south east, which is exposed in Stobgreen Sike at the horizon of the Rookhope Shell Beds. On the upthrow side the Transgression Beds Grit dips north west at 50° towards the Northern Eggleston Fault.

West of Eggleston, the only physical evidence of the Lunedale Fault, within the area mapped, is a dip of 20 to 25° north north east in a small stream exposure of limestone (953228), presumably north of the fault.

Between Bowbank and the Lune, a north ~~west~~ east - south ~~east~~ west fault throws approximately 100 feet south east the base of the Scar Limestone occurring at about 900 feet O.D. to the north west near the Bowbank Road, and at 800 feet O. D. in Lunedale Quarries 300 yards to the south east. ?✓

The Lunedale, Teesdale, and Black Sills faults enclose a triangular area near Eggleston in which the beds have been folded into a north - south syncline. West of the Tees, the general southerly dip into the Stainmore Syncline is modified into a south easterly dip of about 1 in 30, while on Barnley, east of the Tees, the dip is south westerly at about 1 in 23. This synclinal fold becomes shallower to the south, and probably dies out rapidly to the south of the area mapped.

Jointing. - Joint readings have been taken in over 100 localities over the area, most of them in sandstone, as is to be expected from the stratigraphy of the area. Many readings were taken in the various limestones also, as well as some in the tougher shales which sometimes show remarkably good jointing. A histogram has been constructed at 5° intervals. An average set of directions was taken for each locality, and these averages plotted on the histogram. Joints in sandstones, limestones and shales were plotted separately and as a combined analysis. Those in the shales were too few to be of any significance.

The joints in the various limestones over the area show peaks at north 25 to 35° west and north 60 to 75° east. Those in the sandstones reveal a similar trend but with subsidiary peaks at north 40 - 45° west, north 15 - 25° west and north 30 - 35° east. When treated together, two major peaks evolve, the greater at north 25 - 35° west, and a lesser peak at north 60 - 75° east.

Dunham (1933,pp. 241-4) made observation of the joint system as revealed in the Great Limestone in the Stanhope and Frosterly districts of Weardale. Two major peaks persisted on all graphs - north 20 - 25° west and north 60 - 70° east, which correspond reasonably well with the findings of the present analysis. Readings were also taken by him in various other districts, including Middleton-in-Teesdale, in all of which (except for Middleton) the same pair of joint directions predominated. In Middleton the jointing in the Great Limestone showed a dominant maximum at north 45° west, but with north 25° west well represented. The direction north 45° west is poorly represented in the present analysis, especially in the limestones. This is due to the fact that observations were made at various horizons over the area as a whole, and not confined to one horizon, such as the Great Limestone, in a relatively restricted area. With an average for each locality being taken the effect of a large number of localized joints is also minimized.

As pointed out by Dunham (1933) joints in both directions cut each other which gives good reason to suppose their simultaneous origin, thus constituting a conjugate system of shear joints.

Dunham fixed the age of the joints by reference to the Whin Sill, of proven Hercynian age. The sill shows no jointing comparable with that in the sedimentary rocks, the joints therefore ante-dated the injection of the Whin Sill and represent the earliest manifestations of Hercynian tectonics. Trotter and Hollingworth postulated a north - south movement of the block during the earliest phase of late Carboniferous tectonics initiating the east - west Bewcastle anticline. Dunham suggests (1933, 1948, p.75) that this north - south compression was responsible for the formation of the master joints which are symmetrically disposed around the direction of maximum pressure. Wager (1931) proposed a north west - south east compression to account for the master joints in the Craven District, which Dunham (1933) could not support.

The results of the present analysis would seem to support Dunham's suggestion of north - south compression to produce the conjugate joint system. The direction of stress is taken as being the bisectrix of the angle between the directions of maximum jointing. Presumably where one maximum is greater than the second, the direction of stress lies nearer to the greater maximum producing correspondingly greater shear in that direction. This would account for the postulation of a north - south compression rather north north east - south south west compression, which more nearly bisects the two joint directions. The same is true of the present results, the north north west peak being stronger than the east north east, thus suggesting that the stress was north - south rather than north north east - south south west.

STRUCTURAL HISTORY OF THE AREA.

It remains to fit the tectonic history of the present area into the broader picture of events as portrayed by Dunham (1933, 1948) for the Alston Block as a whole.

The first effects of post Carboniferous movements were manifested in the production of the master joints in two major directions, north 25 - 35° west and north 60 - 75° east, under the influence of north south compression as discussed above. There is the possibility that the east - west anticline at Coldberry was also produced by this stress, as well as the broad east - west syncline to the east in the Ayhope Beck - Spurlswood Beck area.

East north east compression which was accompanied by the intrusion of the Whin Sill and the Whin Dykes in east north east tension fissures (such as Knotts Fault) and which was responsible for the Burtreeford Disturbance (a north - south, east facing monocline), was also probably responsible for the north - south anticlines and dome in the Hudes Hope area. The dome structure was probably the result of the superimposition of the north - south anticlines upon the older east - west anticline of Coldberry. These folds are cut across by various faults, as described, and either pre-dated them or were formed simultaneously with the faults. The fact that the Lodgesike - Manorgill Vein cuts obliquely across the east - west anticline strongly suggests that the latter antedated the faulting, which in turn lends support to the suggestion that the north - south folds were superimposed upon an earlier east - west fold. The minor folds east of Great Eggles Hope were probably contemporaneous with the associated faulting or antedated it.

The ? late Hercynian gentle domal uplift of the block with attendant torsion, produced the conjugate vein fissures in north north west, east north east, and east - west to west north west directions. The pattern of the non-mineralized faults closely follow these directions suggesting that some of them at least e.g. the Teesdale Faults which affect the Whin Sill, were either formed contemporaneously, or suffered renewed movement. The Knotts Fault was certainly earlier, being occupied by the Whin Dyke, which it pre-dates. That the vein fissures accompanied the domal uplift is confirmed by the fact that the amount of opening in the hard beds along the veins decreases with depth, which is to be expected where upper beds are stretched relative to lower beds (Dunham 1948,p.71).

The Stainmore Syncline was possibly formed by the early north - south compression. The anticline south of the Northern Eggleston Fault is intimately associated with this major structure and was possibly formed under the influence of block movements which Dunham (1948,p.75) suggests produced normal faulting along the margins, depressing the Alston Block relative to surrounding areas. The Lunedale Fault, of which the Northern Eggleston Fault is a continuation, throws south about 500 feet at Closehouse Mine, but steep dips to the north suggest a former downthrow to the north (Dunham 1948,p.67). It certainly was in existence prior to the intrusion of the Whin Sill, and movement since is evidenced (Dunham 1948,p.62). The stepp northerly limb of the anticline dipping towards the Northern Eggleston Fault, also suggests a former northerly throw. Its present southerly throw is probably the result of uplift along the fault block margins in Tertiary times, which was accompanied by tilting to the east. Another manifestation of this Tertiary Uplift is the ~~easterly~~ easterly regional dip of the area as a whole, which was preceeded by the injection of Cleveland Dykes in an east - west to east south east direction en echelon. Horizontal slickensides in ore bodies, many examples of which are given by Dunham (1948,p.74) can be seen in Bow Lee Beck near the Five Yard Limestone quarry, where a 3 feet wide zone of brecciated sandstone fragments set in calcite occurs in the High Brig Hazle. These denote small sideways movements in Tertiary times. This occurrence is also notable for a horizontally striated and polished surface of limonite (No.96) suggesting some movement since the orebody has been brought within the zone of oxidation, by erosion of the cover.

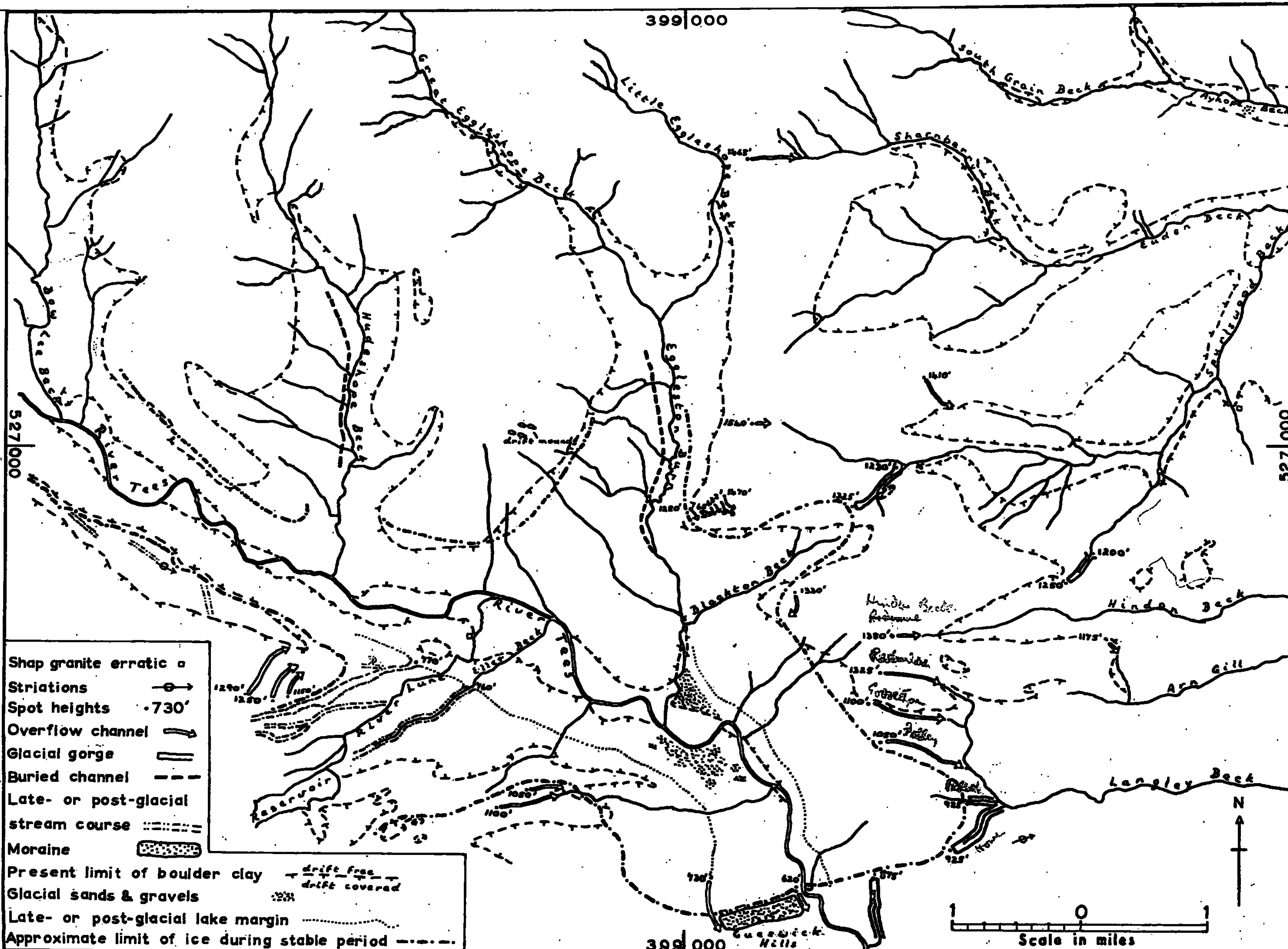


Fig 11. GLACIAL FEATURES OF THE AREA BETWEEN MIDDLETON-IN-TEESDALE AND WOODLANDS

CHAPTER 9.

THE PLEISTOCENE

GENERAL

Dwerryhouse (1902,pp. 572-608) carried out an extensive survey of the glaciology of Teesdale, Weardale, and the Tyne Valley. Of the various conclusions reached, those of main interest to the present account were as follows:

1) That Upper Teesdale was heavily glaciated by ice formed in the upper part of the dale, and on the eastern slopes of Cross Fell.

2) This part of the dale was never invaded by ice from the Irish Sea area.

3) At no time during the period of glaciation was the district completely buried by ice. The higher peaks stood out as nunataks.

4) At the period of maximum glaciation a number of lakes were formed owing to obstruction of the drainage of lateral tributary valleys by the ice of the main glaciers.

5) Lunedale was occupied by ice which came over from the drainage basins of the Irish Sea. Near Middleton-in-Teesdale this ice became confluent with the Teesdale Glacier, the joint stream flowing eastwards.

6) The Teesdale ice was deflected by the thrust of the Stainmore Glacier and caused to flow over into the valley of the Wear, where it became confluent with the Weardale Glacier in the neighbourhood of Wear-Valley junction.

7) During the period of retreat of the ice there was a long interval in the course of which it remained at a constant level, producing well-marked drainage channels.

8) After this interval of constant level the ice retreated

rapidly.

9) Weardale and its tributary valleys above Witton-le-Wear were heavily glaciated by local ice, but this part of the dale was never invaded by ice from outside.

The present area was heavily glaciated, mainly by the Teesdale Glacier, but was also affected by the main stream of the Stainmore Ice, which flowed down Lunedale and became confluent with the Teesdale ice at the junction of the two valleys.

THE GLACIAL DEPOSITS, AND EROSION SURFACES.

The glacial deposits encountered in the area mapped consist of boulder clay bearing numerous boulders and pebbles of Carboniferous limestones and sandstones, together with Whin, and some Borrowdale Volcanic Series erratics, all of which are indigenous to the dale. The Lunedale ice is distinctive in that it carried erratics from the Lake District, including the Shap granite boulders so important in establishing the origin of this stream. During the present survey such an erratic was located in the left bank of the Lune about 285 yards due west of Low Mill farmhouse (964246). The primary surveyors recorded a Shap erratic 1,000 yards due east of Woolly Hills farm, beyond the eastern limit of the present area, and another one in Greenless near the road to Blackling Hole (059273). This was not located, possibly due to the thickly planted fir trees of the Hamsterley Forest. The presence of Whin and Borrowdale Volcanic Series boulders on Woolly Carr Brae, north east of Woolly Carrs, and numerous Whin boulders in the country to the south west testifies to the passage of the Teesdale Ice as well as the Stainmore Ice over Langleydale and Woodland to join with the Weardale glacier in the Bedburn area.

<u>The Tees Valley</u>. - On the right bank of the River Tees, below the Whin scar, great mounds of drift run parallel to the

valley side. These mounds which are particularly well developed near Holwick where they attain a height of 50 feet, are of sub-glacial origin and are in fact drumlins, as postulated by Dwerryhouse (p.575). The drift continues south eastwards below the Whin scar, but ascends the rising Whin north of the Southern Teesdale Fault, finally surmounting the Whin plateau surface west of Middleton Quarries. Above the Whin scar, drift was detected by Dwerryhouse (p. 579) up to a height of 1,500 feet O.D. on Crossthwaite Common. Above this approximate level the land rises steeply to Harter Fell, and it is probable that the drift extended beyond 1,500 feet, but has since been washed away.

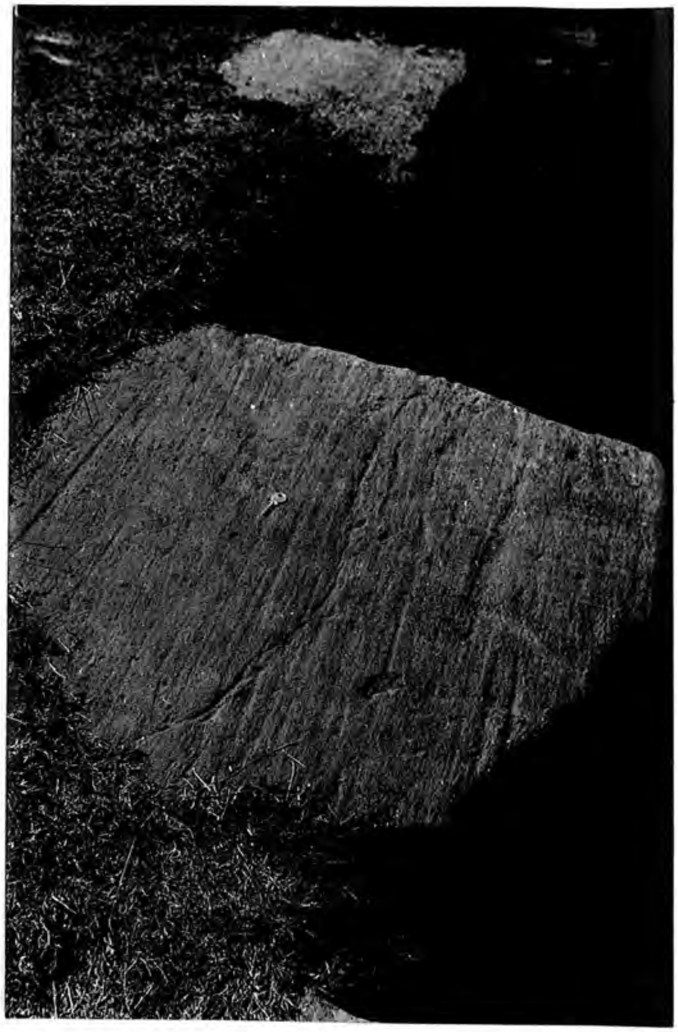
On the flat surface of the Whin Sill below Harter Fell, the drift cover is discontinuous and thin. The bare rock surface is exposed in many places in characteristic roché-moutonee with polished surfaces and feint markings which probably represent weathered striae. Directly above Crossthwaite Quarry, the thin cover of drift has recently been removed from the Whin surface to reveal numerous well preserved striations trending east 35° south. Dwerryhouse (p.587) has described glacial channels in the Whin Sill. These trend roughly parallel to the edge of the scar, and represent stream courses cut during a period when the ice remained at a fairly constant level, but failed to surmount the scar. The most spectacular of these occurs beyond the area mapped and separates The Castles from the main mass of the escarpment. The channel is 100 feet deep and has an average width of 50 yards at the top (Dwerryhouse, p.588). Above West Crossthwaite Oliver Gill occupies a broad, rounded valley of a completely different nature to the more normal gorge-like valleys cut by the post-glacial streams. It is undoubtedly one of the glacial channels, and was cut at an angle to the border of the ice. Rowton Beck, when it flows over the Whin Sill, runs along a rocky gorge which turns through an acute angle near the edge of the scar to run north west. In direct line with this north west - south east channel, a dry, rounded and shallower channel runs south east for 600 yards. This channel affords yet another example of the drainage system of those times. A similar channel runs north west from Wash Beck and according to Dwerryhouse (p. 588) could be seen south east of the beck above Crossthwaite Quarry. Unfortunately quarrying activities have now removed this portion of the channel. Much of the drift on the escarpment must have been removed during that period.

On the northern side of the valley, the Great Limestone forms an intermittent scar at the same level (1,100 to 1,000 feet O.D.), and has a similar flat upper surface where overlying shales etc., have been removed. This surface is largely free of drift, except for a small lobe at Ravelin, and east of Middle Side where the drift ascends onto Tinkler's Allotment. Below the Great Limestone, drift covers the lower slopes of the valley. No channels comparable to those seen on the Whin occur, but the drift may have been removed during this same halt period in the retreat of the ice.

At the mouth of the River Lune, the Teesdale Glacier was joined by the Stainmore Ice flowing down Lunedale (see p. 411). Thick drift occurs in both banks of the Tees downstream. Laky Hill, the Great Limestone outlier in the right bank of the Tees, has the appearance of a roche-moutonnee, its western end having been removed by the river.

Downstream, north of Romaldkirk, the south bank of the Tees is covered with mounds of sand and gravel, many of which have been worked in gravel pits. Croft Yoke Scar reveals boulder clay

Plate 18.



Glacial striations on coarse grit in an old quarry east of Howegill Plantation. Trend is N.50 E.

apparently 60 feet thick below the sand and gravel. Large masses of calcareous tufa which occur along the scar suggest that the drift may not be as thick as it appears, and that some calcareous rock is not far below the surface. The Transgression Beds Grit which has a calcareous cement in places, has been tentatively mapped along this locality.

To the north, in the left bank of Eggleston Burn, near Egglesburn Bridge (989238), at least 30 feet of sand and gravel is exposed, with old gravel pits in its upper surface. These various sand and gravel deposits contain pebbles and boulders of Whin and Borrowdale Volcanic Series, as well as the limestones and sandstones of the dale. The Eggleston Burn exposure shows spectacular current bedding in one section with the foresets dipping into each here.

A notable feature of these sand and gravel deposits is that they do not occur above 725 - 730 feet O.D. and are in all probability fluvio-glacial deposits dumped into a lake ~~limestone~~ or post-glacial lake whose surface lay at about this height (see pp. 428-429).

That the ice stream moved over the high ground north of the Tees is indicated by the fact that drift occurs over Stobgreen and Barnley. On the high ground to the east it is patchy, but mounds of Whin and other pebbles occur at various localities, which have probably been thrown in a heap after being cleared from the fields. Further east, beyond Pallet Crag Gill, the drift becomes thicker, forming an apparently continuous undulating surface. Further evidence exists in the form of striations in grit east of Howegill Plantation, trending north 50° east (pl. 18 ,p. 415).

To the north it occurs in patches on the higher ground of Barnard Castle Allotment (occurring at a height of up to 1,350 feet

O.D.), but is more widespread to the east on Langleydale Common.

<u>The Flushiemere Beck - Bow Lee Beck - Newbiggin Beck area</u> - In the Bow Lee Beck - Newbiggin Beck area drift extends almost up to the base of the Great Limestone in the lower part of the valley, reaching heights of 1,100 - 1,250 feet O.D. Solid rock exposure is confined to the deeply cut valley of Bow Lee Beck, and to lower Newbiggin Beck. Further north, in Bleagill Sike, a tongue of drift extends above the Great Limestone to a height of about 1,700 feet O.D., while in Flushiemere Beck it skirts the Great Limestone just below 1,500 feet O.D. and finally covers it near Rowantreegill Sike, reaching the 1,750 feet contour in the head of the valley. Currick Hill, between Hell Cleugh and Bleak Ley Green Sike is a large drumlin-like mound of drift, and similar mounds occur to the north west.

<u>Hudes Hope</u> - In this valley the main body of drift extends upstream to beyond Hudeshope Head Mine (942298). On the west bank it amounts to as much as 102 feet thick (Skears Mine Vein F) on Tinkler's Allotment, where it is continuous with the Tees valley drift, and reaches a height of up to 1,400 feet O.D. Little solid geology is seen in the west bank below Coldberry. In the east bank solid rocks crop out in the river banks and the larger tributaries such as Snaisgill Sike. Drift extends up to about 1,300 feet O.D., with a patch about 1,600 feet O.D. below Low Monks. At least 20 feet of boulder clay occurs above the Great Limestone in Skears Quarry. It appears to be quite thick in Marl Beck, and Snaisgill Sike, where it extends to the head of the valley just below 1,500 feet. Below Raven Hills, to the east, two pairs of drumlin-like mounds of drift occur just below 1,500 feet O.D., trending south eastwards, testifying to the former presence of the ice in an otherwise drift free area.

North of Hudeshope Head Mine the valley is drift free except for a large patch of boulder clay on the west bank, extending to a height of 1,600 feet O.D. at the base of the Low Grit Sill feature.

The Eggleston Burn - Great and Little Eggles Hope area - In Eggleston Burn thick drift occurs on both banks up to 1,400 feet O.D. on the east, and 1,300 feet O.D. on the west. The thickness of the deposits on either bank is not known, but on the east it is sufficiently thick to mask almost completely the Transgression Beds Grit, which forms a bold feature at least 20 feet high above the drift on the west. Foggerthwaite Allotment and Stotley Carrs present a broad area of undulating drift west of the burn, with no solid exposure except in Horden Sike. Here up to 20 feet of boulder clay surmounts the High Grit Sill. Mounds of sand and gravel occur on the Allotment.

At Middle End, to the north, Great and Little Eggleshope Becks, and Eggleston Burn, have cut through at least 40 feet of boulder clay without revealing solid rock. The drift extends up both the tributary valleys for a mile or so only, although isolated patches of boulder clay occurring in Great Eggles Hope between Manorgill and Black Force (up to 1,500 feet O.D.) indicate its former extent.

In Blackton Beck drift up to 30 feet thick extends to Blackton Head at about 1,300 feet O.D. and sweeps around to Stobgreen Plantation, below Nemour Hill.

The Wear tributaries - In Ayhope Beck the valley bottom has a thick covering of drift which extends up to the Meeting of the Grains, where at least 20 to 30 feet of boulder clay occurs. The drift continues up North Grain Beck, and occurs in patches along South Grain Beck for over a mile to 1,100 feet O.D.

To the south in the Sharnberry area, drift occurs in a large patch south of Black Hill, but the remainder of the higher ground on the Sharnberry - South Grain Beck divide is apparently drift free. The north bank of Euden Beck has a thick blanket of boulder clay which continues westwards to mount the southern side of the valley and cover most of Neighbour Moor, Morton Shield and Sharnberry Flat, extending to heights of up to 1,350 feet O.D. No erratics which can definitely be traced to Teesdale have been located. Any local glacier would have arisen on the high ground of Ever Rigg and Islington Hill, but the wide distribution of drift near the head of this drainage basin strongly suggest that the ice was not local as it could hardly have deposited such extensive material. The ice could have come only from the Eggleston Burn area to the west (see pp. 420 - 421).

That the combined Teesdale - Lunedale ice crossed over into the Wear drainage system in Blackton Beck and to the south east, seems fairly certain. Patches of boulder clay occur near the head of Spurlswood Beck, and on both banks to the east. The south bank, on Woodland Fell, in particular has an apparently continuous, if thin drift cover, with mounds of boulder clay occurring in the Woolly Hills area. On Woolly Carr Brae boulders of Whin and Borrowdale Volcanic Series (Nos.220) occur, proving the former presence of the Teesdale Ice. That it covered Langleydale Common, together with the Stainmore ice, has already been indicated. The area may, or may not have been entirely submerged, drift occurring up to a height of 1,350 feet in the Hindon Beck valley, and on Barnard Castle Allotment. The drift has apparently been removed from the Coal Measure area east of Grey Carrs. The ice probably became confluent with the Wear Glacier in the Bedburn area. It seems very unlikely that the latter ice penetrated into the area mapped from the Bollihope Beck area.

Lunedale - Dwerryhouse (pp. 583-584) was of the opinion that the high ground between Lunedale and Baldersdale was entirely buried beneath the Stainmore ice, the pressure of this ice forcing the Teesdale Glacier northwards along Eggleston Burn and north eastwards over Blackton Head. The lower slopes and valley floor of Lunedale are thickly covered with drift with an undulating surface and numerous mounds which tend to run parallel with the valley, but swing more east - west near the junction with the Tees. In the north bank in particular, long mounds run along the valley side, such as Low Rigg, Middle Rigg, and Seed Rigg. On the higher ground on the southern side of the valley, drift occurs in patches in the more sheltered localities, while a large tongue of drift extends westwards from the Tees to Parson's Moss near the summit of Botany ridge, at a height of over 1,200 feet O.D. In the left bank of the Lune, about 250 yards due west of Low Mill farmhouse, a Shap erratic is embedded in the drift, together with boulders of Whin and dale rocks.

THE LIMITS OF THE ICE DURING THE PERIOD OF MAXIMUM GLACIATION.

The present distribution of drift probably does not indicate the former extension of glacial deposits. It has already been suggested that the drift of the Tees valley extended above its present limit of 1,500 feet O.D. on Crossthwaite Common. The ice probably covered the Flushiemere - Hudes Hope divide below about 2,000 feet O.D., leaving James's Hill as a nunatak. The presence of thick drift on the western slopes of northern Hudes Hope up to a height of 1,600 feet O.D., strongly suggests that the ice moved over the lower ground south of James's Hill. A local glacier probably existed in Hudes Hope, but it seems unlikely that it could deposit such thick drift so near the head of the dale.

Its presence up to a height of at least 1,600 feet O.D. in

Hudes Hope is betrayed by the drift below Low Monks, while the drift mounds below Raven Hills at 1,500 feet O.D. testify to its easterly or south easterly passage here. Dwerryhouse (p.585) mentions an overflow channel between Carrs Hill and Monks Moor. There is no recognisable channel at this point, only a broad saddle, with its lowest point at about 1,760 feet O.D. It seems likely that some ice moved over this saddle into Great Eggles Hope. No drift occurs now, and in common with the slopes at this elevation to the north in Hudes Hope, has probably been removed by subsequent erosion. Carrs Hill and Monks no doubt stood above the ice.

In Great Eggles Hope drift in the northern part of the valley is confined to the valley bottom at about 1,500 feet O.D. Any ice coming over from Hudes Hope was probably reinforced by a small local glacier rising at the head of the valley. There is no apparent reason why drift in this valley should have been eroded more completely than in Hudes Hope, suggesting that the deposits were originally less extensive here than in the latter valley, and were, in the head of Great Eggles Hope, confined to purely local material.

In Eggleston Burn, the situation was different. The Teesdale glacier had more ready access to the valley over the lower ground of Stotley Carrs and Raven Hills, and probably covered the lower ground south of Monks. The Lunedale ice also forced it northwards along the burn and north eastwards into Blackton Beck. At the period of maximum glaciation it must have crossed over into the Wear tributaries, to deposit the drift in the Cloudlam Beck - Morton Shields Beck - Sharnberry Flat area. Whether it covered Islington Hill and Ever Rigg is uncertain, but it must have crossed the slightly lower ground between, and that north of

Plate 19.

A. The seven glacial overflows of Knotts viewed from the north west. The full depth of channels five and six is not revealed from this elevation.

B. The glacial overflow channel at the head of Sharnberry Gill looking west.

Islington Hill. To the south it undoubtedly moved over Blackton Head into the Spurlswood Beck area and probably covered Coldthorn Moss. Grey Carrs may have remained above the ice, together with the higher parts of Stobgreen Plantation. The remainder of the area to the east was covered.

That the part of Lunedale mapped was entirely submerged beneath the Stainmore Ice has already been suggested.

GLACIAL LAKES AND CHANNELS : THE RETREAT PHENOMENA.

To trace the full history of the glacial retreat in the area, one must commence in Eggleston Burn.

The Eggleston Burn Lake. - It has already been stated that the Teesdale Glacier surmonnted the high ground east of the valley, between Ever Rigg and Islington Hill, and between the latter and Jack Scars. There is no evidence of it having ridden over these higher areas. That the ice stood at this level for some time is evidenced by the existence of a shallow overflow channel running east - west across the narrow plateau surface of the Fifth Grit south of Ever Rigg, at a height of 1,540 feet O.D. The absence of a channel east of this short overflow suggests that it ran into a small lake bordering the ice in the Spurlswood - Quarter Burn area. Judging from the shallow nature of the overflow the ice did not remain at this level for a very great length of time.

In the north a spectacular glacial overflow was cut at the head of Sharnberry Gill to a depth of at least 40 feet, the bottom of the channel now being at about 1,465 feet O.D. at its highest point. Its original height must have been about 1,500 - 1,510 feet O.D. The channel is steep-sided, flat bottomed, slightly meandering, and runs eastwards for about 240 yards before its identity is lost in the post glacial river valley.

At the southern end of the lake, in the Knotts area, the first of a series of seven lateral overflows was cut across the narrow spur between Eggleston Burn and Blackton Beck. The bottom of this highest channel is at a height of 1,470 feet, having cut through about 30 feet of sediments. It probably commenced at a height of 1,500 feet or so, and was in part contemporaneous with the Sharnberry overflow. The channel follows a winding course for about 160 yards before ending in the steep slope into Blackton Beck valley.

The second overflow is at a height of 1,430 feet O.D., the original height being about 1,465 - 1,470 feet. The Sharnberry overflow must have ceased to be active shortly after the initiation of this second channel. This latter branches south of the spur, the easterly branch continuing for 140 yards before branching once more, and dying out abruptly, presumably where it flowed into a lake in Blackton Beck. The western branch, at a slightly lower level, dies out in 20 yards.

A third channel commenced at a height of about 1,425 feet to 1,430 feet O.D., and cut down approximately 25 to 30 feet to 1,400 feet O.D. This, and the remaining channels die out rapidly south of the spur, where they drained into the slowly subsiding waters of Blackton lake.

The fourth channel commenced at just below 1,400 feet O.D., cutting its channel base to about 1,375 feet O.D. The fifth channel has its bottom at 1,350 feet having cut through about 20 feet of strata, while the sixth channel cuts through about 15 feet to 1,320 feet O.D. The seventh and final channel had only one bank in solid rock, the right bank having been formed by the glacier. The present form of the channel is of an almost flat shelf, the lowest point being only a few feet lower than the western edge. The left bank was cut through about 15 to 20 feet to a height of 1,280 - 1,290 feet O.D. After this the retreat must have been rapid, for no more channels occur. In this connection the mounds of drift on Foggerthwaite Allotment were probably dumped rapidly during this latter hasty retreat.

Before discussing the Blackton - Stobgreen Lake, the Ever Pools Overflow must be dealt with. This is a channel of about 120 yards in length cut north west - south east across the eastern end of Ever Rigg. The bottom of the channel at its northern end is about 1,400 - 1,410 feet O.D., having cut through approximately 10 to 15 feet of grit. The bottom of the channel is uneven, three depressions now forming small pools. This unevenness is probably due to infallen material from the steep channel sides in post glacial times.

When the ice sheet failed to surmount the high eastern slopes of Eggleston Burn, the main supply of ice was from the south, where it flowed over from Blackton Beck into Spurlswood and thence northwards into Neighbour Moor and the area to the north. A marginal lake must have existed around the ice (its earlier existence has already been inferred in connection with the Ever Rigg overflow - p. 421), with the channel being its only discernible outlet. The channel was cut to about 1,375 feet O.D. at its lowest point in the south east, beyond which it is lost sight of, marking the level of the lake at that time. No further definite channels can be seen to the east along the Euden Beck - Spurlswood Beck divide, though one may have existed west of High Acton Currick (031280) at about 1,280 feet O.D.

<u>The Blackton-Stobgreen Lake</u> - The various channels flowing into this lake over the Knotts spur have already been described. While the first five channels and possibly during part of the time when the sixth channel was active the Blackton-Stobgreen lake extended eastwards into the Spurlswood area, the head of the Blackton valley being

Plate 20.

A. The glacial channel below Howegill Quarries. The V-shaped channel above it on the right is probably post-glacial. The glacial channel probably represents a shallow gorge formed by the ~~recess~~ recession of a glacial waterfall.

B. The glacial channel at the head of Spurlswood Gill. It probably originated in the same manner as the one above.

about 1,325 feet O.D.

During this period there was an overflow cut at the head of Hindon Beck (017245) at a height of 1,380 feet O.D., through which the lake waters escaped to the north east into the Hindon Beck area.

As the ice retreated, a lower channel was cut in Nemour Hill from an original height of about 1,345 feet O.D., to about 1,330 feet O.D. At this period the Blackton and Stobgreen lakes must have been separate, with water flowing from the former into the latter through this channel. At its eastern end the Stobgreen Lake drained to the east through the Redmire Gill overflow. This commenced at a height of about 1,345 - 1,350 feet O.D. and was cut down to 1,325 - 1,330 feet O.D. so that the two channels were roughly contemporaneous. The channel maintains its identity eastwards, falling to a height of 1,175 feet O.D. or less, which suggests that the level of water east of Stobgreen was much lower than that in the Stobgreen lake. The level c the ice must have been near this height (all these lakes were probably marginal to the ice in each valley), and swept around Langley Common into Hindon Beck. The marginal waters west of the ice in Hindon Beck, escaped to the south through a shallow channel at 1,175 feet O.D., situated about 500 yards south south west of Woolly Hill farm (042245).

With further retreat of the ice, the Blackton lake shrank in size and became confined to the Blackton valley. At the head of Spurlswoo a channel commences at a height of 1,325 feet O.D. (see pl. 19B, p. 424) is cut to a depth of about 30 feet, and drains north eastwards into Spurlswood. The south western end of the channel is plugged with peat, ends abruptly, and certainly does not cut through to Blackton Head. It's formation was probably due to the cutting back of a 87 waterfall where melt water plunged over the edge of a glacier. It was evidently formed during a period when the ice was no longer being forced over into Spurlswood, but retreating, slowly at first, then rapidly, preventing the completion of the gorge through Blackton Head. The fact that a waterfall was formed indicates that any lake into which it may have flowed had its level below the bottom of the channel (1300 feet at its western end and about 1220 feet at its eastern end), so that the Blackton lake at this time must have stood below 1,325 feet O.D., the elevation of Blackton Head. This channel must have been contemporaneous therefore, with one or both of the two lowest channels on Knotts.

A similar channel was cut south west - north east on Woolly Hills, losing its identity at about 1,200 feet O.D. where it presumably flowed into a marginal lake on Woodland Fell. At its south western end it ends abruptly, once more suggesting a gorge terminating in a waterfall. The ice must have stood at about 1250 feet O.D. (the height of the head of the channel) in Hindon Beck. This means that it was contemporaneous with the development of the Redmire Gill overflow in its earlier stages. With the ice at about 1250 feet O.D. in Hindon Beck, the overflow south south west of Woolly Hills farm would have been submerged by ice, and therefore the Redmire Gill overflow would not have been cut down to the present level (about 1175 feet O.D.), both these channels flowing into the sam lake.

Consideration of the level of the bottom of the Redmire Gill overflow at its western end (1325 - 1330 feet O.D.) indicates that it was abandoned prior to the cutting of the Spurlswood overflow, which in turn means that the latter was of later development than the Woolly Hills overflow. Yet the Woolly Hills overflow channel is cut to 1200 feet O.D., while the Spurlswood overflow at its deepest en is about 1220 feet O.D. On the face of it this seems difficult to explain (but see pp. 431-432).

The Redmire Gill overflow then, was abandoned roughly at the same time as the lower Knotts channels were being cut. The next channel was cut at a height of about 1,200 feet O.D., to 1,180 feet O.D., suggesting a rapid retreat of the ice in the intervening period. To the east this channel, cut along Goose Tarn Beck, loses its identit at about 1,075 feet O.D. or less, once more suggesting a lower lake level to the east. see w

A third channel was cut south of Bracken Head 7S, running eastwards to Pallet Crag, its western end commencing at about 1,100 feet and cutting down to approximately 1,055 feet O.D. This was probably bordered on the south, by the glacier for much of the time but discussion of this channel is better deferred and incorporated in the section dealing with the Tees lake.

<u>The Tees - Lunedale lakes</u> - The Tees valley is remarkably free of overflow channels until we reach the Lune Valley junction. Here at Kirk Arran (939238), there were two overflows just west of the knoll at heights of about 1,290 feet and 1,250 feet O.D. and another to the east at 1,150 feet O.D. Three dry channels, (one named Ram Gill) run down the slopes of Crossthwaite Common from these overflows losing their identities at about 1,100 feet O.D. Dwerryhouse (pp. 587- 588) has already drawn our attention to the probably long halt period in the glacial retreat in Teesdale, during which a series of lateral channels were cut into the Whin Sill (see pp.413-14).At this time the ice stood at a height of about 1,100 feet O.D. The existence of the channels in the Whin surface indicates that no latera lake existed at this time. The dry channels were therefore probably glacial overflows along which melt water flowed from the Lunedale Lake, at this time at a level varying from approximately 1,290 to 1,150 feet O.D.

On the southern side of Lunedale, two channels occur on Toddyshaw Hill and Bail Hill at heights of 1,100 feet O.D. and 1,050 feet O.D., which were cut later than the Kirk Arran overflows, but still during the stable period. The nature of the channels is such as to indicate the presence of a lake in Lunedale, draining eastwards into Teesdale. The level of the Lunedale Ice appears to have been slightly higher than that in Teesdale.

To the south east there is further evidence of this stable period. The channel at a height of 1050 feet O.D. south of Bracken Heads has been described. Of greater significance are three glacial channels E. of Rowlands beck situated at Pallet Crag quarries (925 feet O.D.) (see pl. 20 A, p. 424), in Howe Gill (925 feet O.D.), and below High Shipley (875 feet O.D.). These are not true overflows, but represent gorges formed by the cutting back of waterfalls, similar in every respect to those already described. Above them poor intermittent channels may exist over a short distance. The absence or poor development of such channels suggests that the powerful streams flowed over or through the ice. These channels were evidently formed during a period when the level of the ice was such as to maintain a small lobe of ice overlapping from the Tees valley on to the top of the north eastern bank as far as Pallet Crag and Roger Moor, but no further. To the east, any ice remaining was detatched from the main body in the Tees.

It is significant that the only terminal moraine in Upper Teesdale (with the possible exception of the mound of clay and gravel at the Tees-Harwood Beck confluence, Dwerryhouse p. 587), was that recorded by Reading (1954, p. 187) at Queswick Hills, under a mile south west of High Shipley, which he describes as large. It seems certain that the ice remained static at this point, building up a large terminal moraine at Queswick Hills while the various channels discussed were formed. The ice must have remained at this level for a fairly long period, sufficiently long for gorges at least 60 feet deep to be cut through 35 feet of sandstone and the underlying beds, for distances of 400 yards (Pallet Crag Quarries), 900 yards (Howe Gill) and about 500 yards (High Shipley).

After this the main ice disappeared rapidly, but a mass of ice must have remained isolated on the north east bank, as a series of shallow glacial channels (now dry) have been cut into the drift, draining <u>westwards</u> to Folly Bank and <u>south west</u> towards Folly House.

A lake formed behind the Gueswick Hills moraine, finally escaping via a channel probably on the site of the present Tees, and another channel west of the hills along which the railway now runs, at a height of 725 feet O.D. (Reading,p.187) (nearer 730 feet O.D.). The original height of this latter channel must have been about 750 feet O.D. Further evidence of the existence of the lake occurs in Lunedale Eller Beck is now almost streamless and has a typical glacial channel cross section, being steep sided, and flat bottomed. It lies in direct line with Merry Gill, which now flows into the Lune, a clear case of stream capture. The Eller Beck valley dies out in the drift west of Mickleton at about 760 feet O.D. Evidently it flowed into a lake whose margin lay at this height, the lake being that one dammed behind Gueswick Hills. The discrepancy in height of the channels may be of no significance because of the uncertainty regarding the height of any point prior to the cutting of a channel.

To the north a similar channel runs east west through Bowbank and dies out in a deep hollow west of Lune Bridge at about 770 feet O.D. The valley is now dry. This must have drained into the lake at this level. Both these channels were normal streams and not overflows, so one would expect them to cut their courses down to lake level as the lake retreated. There is no apparent reason why one should suddenly be abandoned at 770 feet O.D., and a second one to the east, at 760 feet O.D. when both drained into the same lake. Eller Beck is dry because of river capture by the Lune, the Bowbank channel because ther

Plate 21.

An incised meander cut through the Grit Sills in Eggleston Burn. The gorge is post glacial in origin and opens out to north and south into a maturer valley. It is thought to be a diversion from the pre-glacial stream course, which probably lies to the west buried beneath thick drift. The drift scar on the right in the middle distance probably lies on the line of the buried channel.

is no catchment area (presumably the climate is drier now). One is faced with the problem of two streams flowing into the same lake at different levels.

BURIED CHANNELS

A level driven along Hall's Vein in the west bank of Hudeshope Beck, passed from the Great Limestone at 270 feet from the portal into boulder clay which continues to 720 feet, when it re-entered solid rock, (Dunham 1948, p. 305). This 450 feet wide wedge of boulder clay infills the pre-glacial channel of Hudeshope Beck. It can be seem from Dunham's cross section of the level (p. 303) that the pre-glacial channel is at least 40 feet deeper than the present river channel, which cuts a deep meandering gorge through the Great Limestone at Skears Sears. This gorge is fault bounded, the limestone being let down between the faults. To the north and south the valley broadens out and takes on a maturer form. It is noticable that solid exposure in the valley sides is confined to the east bank both north and south of the gorge, so that the pre-glacial channel lies west of the present course for much of the length of Hudes Hope, south of Coldberry. The Great Limestone exposures in How Gill offer a western limit for the position of the channel.

A similar channel probably exists in Eggleston Burn. Southwards from East Skears to the Druvy Burn confluence the burn has cut a meandering gorge up to 100 feet deep through the Grit Sills, for a distance of about 2,500 yards (see pl. 21, p. 429). To the north and south the valley has a broader, more mature appearance. The only solid exposures to the north occur in the east bank until we reach East Rake Hush in Great Eggles Hope. To the south, solid outcrops are again confined to the east bank for over 1,000 yards. The pre-glacial valley must once more occur to the west of the present river course. In the north a western limit for its position can be fixed in Horden Sike, where the top of the High Grit Sill crops out about 500 yards west of Eggleston Burn. Downstream from here to the Eggleston Burn confluence, the sike runs through boulder clay. At the southern end of the gorge, thick grit at East Skears Foot gives way to the west to thick boulder clay for over 165 yards, before grit is once more exposed at the confluence of Druvy Burn and Slaggy Sike.

It is noticeable that in Hudeshope Beck below Coldberry, and in Eggleston Burn (i.e. in north - south courses) the streams run well east of the centre of the valley, and that the valleys have steeper eastern banks along these parts. North of Coldberry the stream runs north west - south east, and no channel diversion has occurred, similarly in Great Eggles Hope, running north west - south east, the post glacial stream has re-excavated the previous channel.

D. Mayling (personal communication) has traced many such buried channels in the north - south tributaries of Weardale, and in each case the diversion has been to the east, with solid exposures being confined to the eastern banks of the streams in appropriate sections.

The Tees south of Eggleston follows a roughly north - south course, running through a steep sided gorge, and Reading (p.182) has suggested the presence of a pre-glacial channel to the west. At the junction of the Balder with the Tees both cut down through high cli[illegible] of grit. Just upstream from the confluence, the Balder flows through very thick drift. This is suggested as the pre-glacial channel by Reading.

The cause of this easterly migration of north - south streams is not certain. It could be due to the deposition of thicker drift on the eastern slopes of the valleys from an ice-sheet moving east-west. The foregoing account of the deposits in Hudes Hope and Eggleston Burn does not suggest that the drift deposits are thicker on the west banks as a whole. There is certainly no recorded thickness on eastern Hudes Hope to compare with the 102 feet encountered when sinking Skears Mine Vein F shaft, but drift does extend to a greater height than on western Hudes Hope. In Eggleston Burn the east bank drift again extends to a greater height, and appears to be every bit as thick as the west bank deposits. In the Tees valley below Eggleston, however, the west bank drift is certainly thicker than that on the east.

The weight of the ice at its maximum must have been fairly considerable. After its removal it seems probable that an adjustment in the level of the land followed. This adjustment might have been accompanied by a slight easterly tilt (there is evidence of movement since the mineral veins have been brought within the zone of oxidation -see p. 410). Such a tilt, and it need only be slight, would result in an easterly (down slope) migration of the post glacial north - south streams relative to the pre-glacial channels. These would then cut into the east bank of the buried valley, forming rocky gorges when conditions were suitable.

Such a tilt would also clear up other problems. It will be recalled that there was difficulty regarding the contemporaneity or otherwise of the Spurlswood and Woolly Hills channels and the Redmire Gill overflow. The Woolly Hills channel must have been earlier than the later period of activity in the Redmire Gill overflow whose eastern end was cut to a level below that at which the ice must have stood to give rise to the other channel. The Spurlswood channel was cut at a time when the Blackton-Stobgreen lake level stood below 1,325 ft. O.D., yet the bottom of the Redmire Gill channel at its western end is at 1,325 - 1330ft. so that is was abandoned before the commencement of the channel at the head of Spurlswood. The latter flowed into a lake with a level of about 1220 ft.O.D. The

Woolly Hills channel flowed into a lake with a level of 1,200 ft.O.D. The lake must have been the same one (or in the same area) and yet the Woolly Hills channel antedated the Spurlswood channel, but flowed into an apparently lower lake level. If we allow for a post glacial tilt, a matter of something over 20 ft. in about 3,700 yds., or over 1 in 560, there would be no problem, the Woolly Hills channel flowing into a lake level relatively higher than 1,220 ft.O.D.

Similarly the discrepancy of 10ft. or so in the level of the lake into which the now dry streams of Lunedale flowed would also be accounted for, involving an allowance for a fall of about 1 in 600.

What is needed to definitely establish such a post glacial tilt, is the existence of a definite glacial lake shoreline which cuts across the contour. Because of the possibility of such a tilt no lake margins (other than that dammed by the Gueswick Hill moraine) have been inserted on the accompanying map of the glacial phenomena of the area.

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APPENDIX.

ROCK SPECIMEN AND FOSSIL LOCALITIES.

In the present work each field slip used in the detailed mapping of the area has been given an index letter, the letter being printed on the back of the field slip. Each rock sample or fossil locality was then located on the map with the appropriate index letter followed by a number, e.g. A7, G24, etc. This system has been adopted to facilitate quicker reference from specimen to locality and vice versa.

In the laboratory the rocks and fossils were given numbers only, to simplify the procedure of reference to the specimens in the text. A list of specimen numbers and corresponding locality indeces is given below:

Specimen number.		Locality index.
1	A1.	Hudeshope Beck.
2	A2.	Throstle Gill, Hudeshope Beck.
3	A4.	Hudeshope Beck.
4	A5.	Mouth of How Gill, Hudeshope Beck.
5	A6.	How Gill.
6	A7.	Snaisgill Sike.
7	A9.	" " .
8	A10.	Crags, east of Hudes Hope.
9	A11.	Black Edge, below Raven Hills.
10	A12.	Snaisgill Sike.
11	A13.	Old hush north of Skears Scars.
12	A14.	Hudeshope Beck north of Skears Scars.
13	A15.	" " .
14	A16.	" " .
15	A17.	" " .
16	A18.	Low Skears, Hudeshope Beck.
17	B1.	Intake Sike.
18	B2.	Bridge Sill, River Tees.
19	B3.	Howgill Sike.
20	B4.	" " .
21	B5.	Laky Hill, River Tees.
22	B6.	Tofts Bank, River Lune.
23	B7.	River Lune, near Lunedale Quarries.
24	B8.	" Tees, west of Middleton Bridge.
25	B10.	Howgill Sike.
26	B11.	Lonton Limekiln.
27	B12.	River Tees east of Bridge Sill.
28	D1.	" " .
29	D2.	Breckholm Pool, River Tees.
30	D3.	About 600 yards east of Crossthwaite Quarry
31	D4.	Below Crossthwaite Quarry.
32	D5.	Breckholm Pool.
33	D6.	" " .
34	D7.	Oliver Gill.

Specimen number.		Locality index.
35	E1.	Mouth of Intake Sike.
36	E2.	" " " " .
36a	D8.	Crook Pool, River Tees.
37	F1.	" " " " .
38	F2.	River Tees, below Broken Way.
39	F3.	Owl Gill.
40	F4.	Stony Gill.
41	F5.	Newbiggin Beck.
42	F6.	Unthank Bank, River Tees.
43	F7.	" " " " .
44	F8.	" " " " .
45	F9.	River Tees, east of Unthank Bank.
46	F10.	Park End Beck.
47	F11.	Unthank Bank.
48	F12.	River Tees below Unthank Bank.
49.	F13.	Unthank Bank.
50	F14.	" " .
51	F15.	River Tees/Holwick Beck confluence.
52	F16.	Mill Beck.
53	F17.	" " .
54	G1.	Newbiggin Beck.
55	G2.	" " .
56	G3.	Silver Hill, east of Newbiggin Beck.
57	G4.	High Crags, " " " " .
58	G5.	Old Quarries south of Red Grooves.
59.	G6.	Coldberry Gutter.
60	G7.	" " .
61	G8.	Red Grooves.
62	G9.	Coldberry Gutter.
63	G10.	" " .
64	G11.	" " .
65	G12.	" " .
66	H1.	Old hush south of Marl Beck.
67	H2.	" " " " " " .
68	H3.	Longmire's Gutter, Hudes Hope.
69	H4.	" " " " .
70	H5.	" " " " .
71	J1.	Racketgill Sike, Hudes Hope.
72	A19.	Snaisgill Sike.
73	A20.	Old Quarries north of Stotley Grange.
74	A21.	Snaisgill Sike.
75	B13.	Stream east of Howgill Sike.
76	E3.	Intake Sike.
77	E4.	Old quarry west of Foggerthwaite Quarry.
78	E5.	Red Scar Quarry, River Tees.
79	E6.	Foggerthwaite Quarry.
80	E7.	Near mouth of Bell Sike, Eggleston Burn.
81	E8.	" " " " " " " .
82	E9.	Eggleston Burn.
83	E10.	" " .
84	E11.	" " .
85	E12.	" " .
86	E13.	" " .
87	E14.	" " .
88	E15.	" " near Egglesburn Bridge.
89	E16.	Quarries west of Knotts Plantation.
90	E17.	Eggleston Burn near Blackton Bridge.
91	E18.	Whistle Crag.

Specimen number.		Locality index.
92	E19.	Nemour Hill.
93	G13.	Bow Lee Bridge.
94	G14.	" " Beck.
95	G15.	" " " .
96	G16.	" " " .
97	G17.	" " " .
98	G18.	" " " .
99	G19.	Mirk Holm, Bow Lee Beck.
100	G20.	Red Grooves Hushes.
101	G21.	Coldberry Grains.
102	G22.	Stable Green Quarry, east of Newbiggin Beck.
103	H6.	Manorgill Hushes.
104	H7.	" " .
105	H8.	" " .
106	H9.	" Sike.
107	H10.	" Hushes.
108	H11.	" " .
109	H12.	Head of Manorgill Sike.
110	H13.	" " " " .
111	H14.	Manorgill Sike.
112	H15.	Low Carrs, east of Hudeshope Beck.
113	H16.	Monk's Moor, north of Low Monks.
114	H17.	" " , in stream east of Monks.
115	H18.	Head of Manorgill Sike.
116	H19.	Southern end of Carrs Hill.
117	J2.	Old Quarry near mouth of Manorgill Sike.
118	J3.	Great Eggleshope Beck.
119	J4.	Black Force, Great Eggleshope Beck.
120	J5.	Lodgegill Sike/Gt. Eggleshope Beck confluenc
121	J6.	Great Eggleshope Beck.
122	J7.	" " " .
123	J8.	Manorgill Sike.
124	J9.	Racketgill Hushes, Hudes Hope.
125	J10.	" " " " .
126	K1.	Knotts Hole, East of Eggleston Burn.
127	K2.	Old Quarry west of Knotts.
128	K3.	" " " " " .
129	K4.	" " at East Skears, Eggleston Burn.
130	K5.	Eggleston Burn.
131	K6.	" " .
132	K7.	Old Quarry in tributary of Druvy Burn.
133	K8.	Head of Slaggy Sike.
134	K9.	Horden Sike.
135	K10.	Old Quarry in tributary of Horden Sike.
136	K11.	Tributary of Horden Sike.
137	K12.	" " " " .
138	K13.	Millstone Rigg.
139	L1.	East Rake Hush, Great Eggles Hope.
140.	L2.	" " " " " " .
141	L3.	" " " " " " .
142	L4.	" " " " " " .
143	L5.	Stream running into East Rake Hush.
144	L6.	" " " " " " .
145	L7.	" north of East Rake Hush.
146	L8.	Great Eggles Hope.
147	L9.	Wheel Crag, east of Eggleston Burn.
148	L10.	Little Eggles Hope.

Specimen number.		Locality index.
149	L11.	Little Eggles Hope.
150	L12.	" " " .
151	L13.	" " " .
152	L14.	West Rake Hush, Great Eggles Hope.
153	L15.	Stream north of East Rake Hush.
154	L16.	Little Eggles Hope.
155	M1.	Great Eggles Hope.
156	M2.	" " " .
157	M3.	" " " .
158	N1.	Wire Gill, Great Eggles Hope.
159	N2.	" " " " " .
160	N3.	" " " " " .
161	N4.	" " " " " .
162	N5.	Hush in left bank of Gt. Eggleshope Beck.
163	N6.	" " " " " " " " .
164	N7.	Little Eggles Hope.
165	N8.	" " " .
166	N9.	" " " .
167	N10.	Sharnberry overflow channel.
168	N11.	Little Eggles Hope.
169	N12.	Dusty Gill, Gt. Eggles Hope.
170	N13.	Sharnberry overflow channel.
171	O1.	Hudeshope Beck.
172	O2.	" " .
173	O3.	" " .
174	O4.	Hudeshope Grains.
175	O5.	" " .
176	O6.	" " .
177	O7.	" Beck.
178	O8.	" Grains.
179	O9.	" " .
180	O10.	" " .
181	O11.	Coving Sike, Hudes Hope.
182	O12.	Weather Beds, " " .
183	O13.	Hudeshope Grains.
184	O14.	Rowantreegill Sike.
185	O15.	" " .
186	O16.	" " .
187	O17.	Bleagill Sike.
188	O18.	" " .
189	O19.	Hudeshope Grains.
190	O20.	Head of Bleagill Sike.
191	P1.	Sharnberry Gill, near Sharnberry Lead Mine.
192	P2.	" " " " " " .
193	P3.	" " " " " " .
194	P4.	Old Quarries at mouth of Nanny Sike.
195	P5.	Sharnberry Gill.
196	P6.	" " .
197	P7.	" " .
198	P8.	South Grain Beck.
199	P9.	Sharnberry Gill.
200	Q1.	Cloudlam Beck.
201	Q2.	" " .
202	Q3.	" " .
203	R1.	Slate Ledge.
204	R2.	Spurlswood Gill overflow channel.
205	R3.	" " .
206	R4.	" " .

Specimen number.		Locality index.
207	R5.	Tributary of Quarter Burn.
208	R6.	Spurlswood Gill.
209	R7.	" " .
210	R8.	" " .
211	R9.	" " .
212	S1.	" " .
213	S2.	" " .
214	S3.	The Springs.
215	S4.	Green Less.
216	S5.	" " .
217	S6.	Spurlswood Gill.
218	S7.	" " .
219	T1.	Old Quarries at head of Woolly Gill.
220	T2.	Woolly Carr Brae.
221	U1.	Old Quarries west of Woolly Gill.
222	U2.	" " " " " " .
223	U3.	Grey Carrs area.
224	U4.	" " .
225	U5.	" " .
226	V1.	Old Quarry in Oak Bank, Spurlswood Gill.
227	V2.	Oak Bank.
228	V3.	Spurlswood Gill.
229	V4.	Front Plantation, Spurlswood Gill.
230	V5.	King's Crag, Euden Beck.
231	V6.	Forestry road off Pennington Rigg.
232	V7.	Old Quarries, Euden Beck.
233	V8.	" Quarry east of Spurlswood Gill.
234	V9.	Euden Beck.
235	B14.	Sun Bank, north of River Tees.
236	U6.	Grey Carrs.
237	F18.	Head of Brokersgill Sike, near Ravelin Shop.
238	A22.	Mouth of How Gill, Hudes Hope.
239	A23.	Hudeshope Beck below Skears Quarry.
240	A24.	South of Gate Castles Quarry, Brown Dodd.
241	B15.	Hudeshope Beck.
242	B16.	Howgill Sike.
243	C1.	Old Gravel Pits south of Croft Yoke Lane.
244	C2.	Croft Yoke Scar, River Tees.
245	C3.	" " " and River Tees.
246	C4.	Black Sills, River Tees.
247	C5.	" " " " .
248	C6.	Tophet Hole, River Tees.
249	C7.	" " " " .
250	C8.	Skirtle Bank, River Tees.
251	C9.	Old Quarry, Hayberries Plantation.
252	C10.	Hayberries Plantation.
253	C11.	East Pasture.
254	C12.	Old Quarry south of Black Hill Plantation.
255	C13.	" " , Waddy Carr.
256	C14.	Black Hill Road.
257	C15.	Hell Beck, near Eggleston Bridge.
258	C16.	" " .
259	C17.	Great Wood, left bank of River Tees.
260	C18.	Opposite Skirtle Bank, River Tees.
261	C19.	Limekiln Hole, River Tees near Eggleston.
262	C20.	Stobgreen Sike, near Town Head.
263	C21.	" " " " " .
264	C22.	" " " " " .

Specimen number.		Locality index.
265	D9.	Oliver Gill, Crossthwaite Common.
266	D10.	Tributary of Willy Brig Sike.
267	D11.	" " " " " .
268	D12.	Easter Beck, Crossthwaite Common.
269	E20.	Blackton Beck.
270	F19.	Brokersgill Sike.
271	F20.	" " .
272	F21.	Newbiggin Beck.
273	F22.	Sand Force, Rowton Beck, Crossthwaite.
274	F23.	Old Levels near Scoberry Bridge.
275	F24.	River Tees, near Scoberry Bridge.
276	G23.	Hell Cleugh, Bow Lee Beck.
277	G24.	Mirk Holm, Bow Lee Beck.
278	G25.	Bow Lee Beck.
279	G26.	Hell Cleugh, Bow Lee Beck.
280	U7.	Stobgreen Sike.
281	U8.	" " .
282	U9.	" " .
283	U10.	" Plantation.
284	U11.	" " .
285	U12.	Head of Redmire Gill overflow channel.
286	U13.	Death Nook, Stobgreen Plantation.
287	U14.	Curricks on Barnard Castle Allotment.
288	U15.	Barnard Castle Allotment.
289	U16.	Tributary stream of Redmire Gill.
290	W1.	Hawke Sike Gill, tributary of Ayhope Beck.
291	W2.	" " " .
292	W3.	Tributary stream of Ayhope Beck.
293	X1.	Old Quarry east of Folly Head.
294	X2.	Pallet Crag Gill.
295	X3.	Old Quarry west of Howlsworth.
296	X4.	Folly Head overflow channel.
297	X5.	Pallet Crag Gill.
298	X6.	" " " .
299	X7.	Howegill Quarries.
300	X8.	" " .
301	X9.	Pallet Crag.
302	X10.	Langley Beck.
303	X11.	Old Quarry north of Pallet Crag House.
304	X12.	" Quarries east of Howegill Plantation.
305	X13.	Small stream " " Gate House.
306	X14.	Old Quarry north of East Barnley.
307	X15.	Stream section east of above location.
308	Z1.	Old Quarry near Bail Hill House.
309	Z2.	Bail Hill Quarries.
310	Z3.	Old Quarry, West Pasture Road.
311	Z4.	" " , south of West Pasture Road.
312	Z5.	Blackrigg Quarry.
313	Z6.	Old Quarry, Parson's Rigg.
314	Z7.	Shields Beck.
315	Z8.	Swarthy Mere.
316	Z9.	Shields Beck.
317	Z10.	" " .
318	Z11.	Old Quarries north of West Pasture Road.
319	Z12.	River Lune.
320	Z13.	" " .
321	Z14.	Wester Beck.
322	Z15.	" " .

Specimen number.		Locality index.
323	Z16.	Easter Beck.
324	Z17.	" " .
325	Z18.	River Lune, Lunedale Quarries.
326	Z19.	" " .
327	Z20.	Hell Gill, Bow Bank.
328	Z21.	East Park.
329	X16.	Old Quarry, east of Pallet Crag Gill.
330	T3.	Coal tips north of Hindon Beck.
331	T4.	Old Quarries west of Woolly Hill farm.
332	X17.	Small stream east of Pallet Crag Gill.
333	?B9.	" " " " Middleton.
334	G27.	Bleagill Sike below Bleagill Bridge.
335	G28.	Hush east of Bleak Ley Green Hush.
336	A25.	Tributary of Snaisgill Sike.
337	O21.	Bales Hush, Bales Allotment.
338	O22.	Rowantreegill Sike.

GEOLOGY OF THE AREA
BETWEEN
MIDDLETON-IN-TEESDALE
AND
WOODLANDS
KEY
BC Brockwell Coal
CM Coal Measures
V Fifth Grit
IV Fourth Grit
III Third Grit
II Second Grit
MS Marine Siltstone
I First Grit
GS Grindstone Sill
FS Fossil Sandstone
UFL Upper Felltop Limestone
HS Hipple Sill
CMB Coalcleugh Marine Band
TBG Transgression Beds Grit
LFL Lower Felltop Limestone
RSB Rookhope Shell Beds
RS on map
HGS High Grit Sill
LGS Low Grit Sill
GrS Grit Sills
KS Knucton Shell Beds
CL Crag Limestone
FiS Firestone Sill
PS Pattinson Sill
LL Little Limestone
CS Coal Sills
GL Great Limestone
IP Iron Post Limestone
FF Four Fathom Limestone
TY Three Yard Limestone
FY Five Yard Limestone
SL Scar Limestone
CS Cockle Shell Limestone
SP Single Post Limestone
WS Whin Sill
TL Tynebottom Limestone
Ft.
400
300
200
100
50
0
EAST TEESDALE
WEST TEESDALE
SCALE
0 1/4 1/2 1 2 MILES
DIP →
FAULT
VEIN
H.L.I.L.J. 1956
MIDDLETON COMMON
NEWBIGGIN COMMON
MIDDLETON IN TEESDALE
PIKESTONE FELL
HAMSTERLEY FOREST
HAMSTERLEY COMMON
EGGLESTON COMMON
EGGLESTON
WOODLAND FELL
WOODLAND
HOLWICK
CROSSTHWAITE COMMON
ROMALDKIRK
MICKLETON
LANGLEYDALE COMMON